FOREST PRODUCTS JOURNAL

FOREST PRODUCTS RESEARCH SOCIETY

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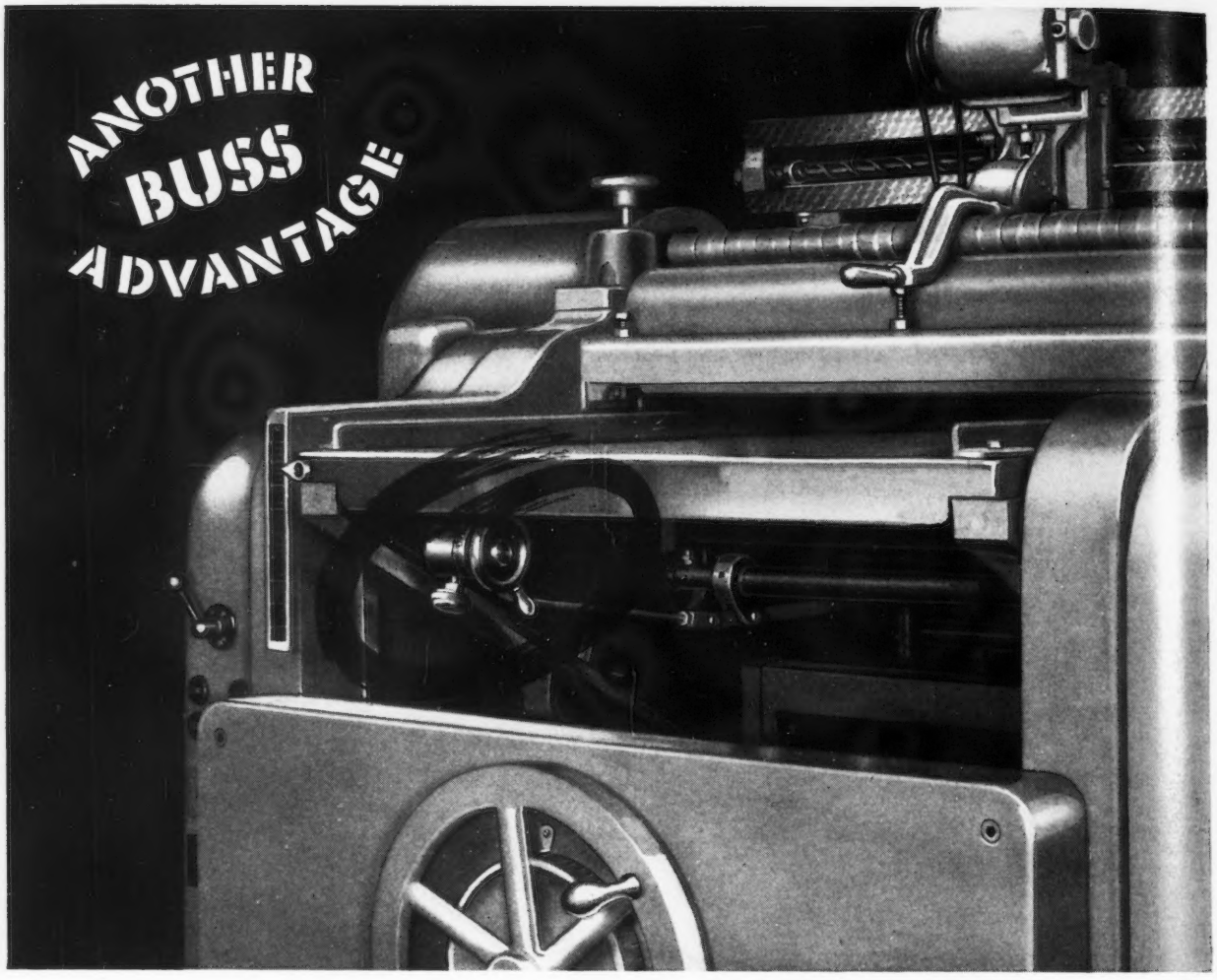
1960/MAY



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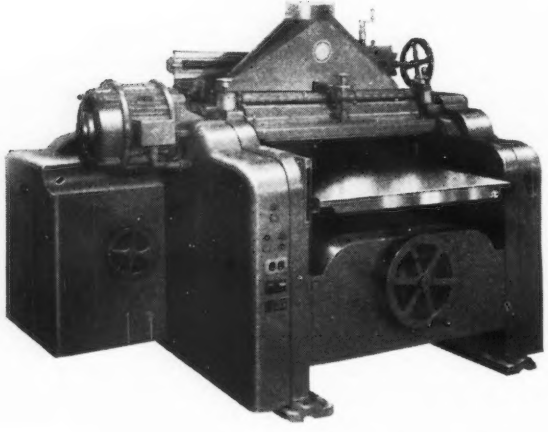

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FOREST PRODUCTS JOURNAL

Vol. X, No. 5 May, 1960

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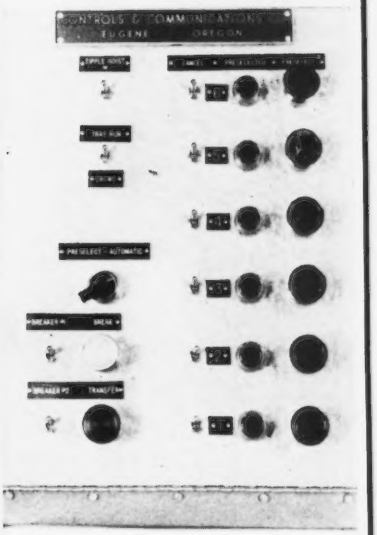

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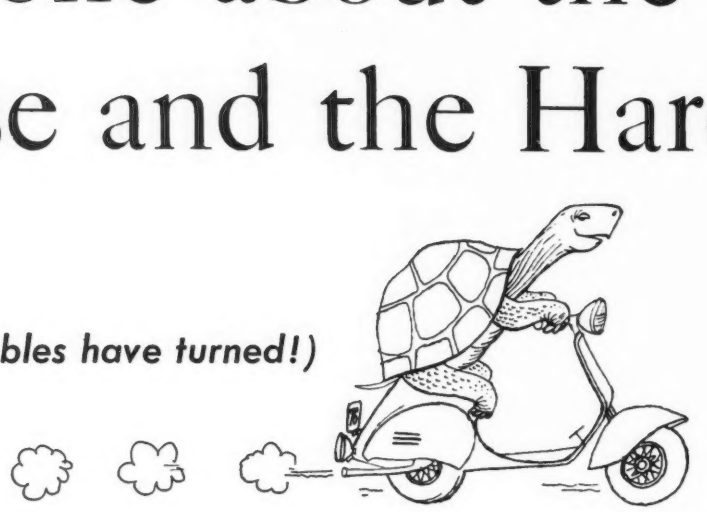
Have you heard this one about the Tortoise and the Hare?

(or: how the tables have turned!)



Of course you know the old fable about the tortoise and the hare . . . the rabbit was so confident he'd win that he took a siesta under a tree — and old "slow but steady" turtle won the race.

But that *is* a fable when it comes to wood furniture — because "slow but steady" isn't good enough for today's furniture manufacturer whose profits can be made or lost in his cost accounting. What his manufacturing methods and his furniture products *really* require is the slogan "fast but steady".

Take glue-setting for example. In core binding, joint assembly, edge bonding, veneering, etc., furniture-in-the-making used to have to spend a turtle-slow period of time standing stiffly in clamps, before taking the next step. A real bottle-neck — or, may we say, turtle-neck!

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For no fables, but some facts, you may be interested in writing to Reichhold for *Technical Bulletin G-16* on RCI 9159 PLYAMUL. This quality Reichhold product may not multiply your profits like rabbits — but will speed up that turtle-like production step when time is money.

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IMPORTANT: PLEASE ATTEND YOUR ANNUAL BUSINESS MEETING MONDAY, JUNE 6, 11:30 a.m.–12:30 p.m.

FPRS News-Digest

Official Program for FPRS 14th National Meeting in Montreal, Canada, June 5-9

The Queen Elizabeth Hotel, in historic and hospitable Montreal, will be the headquarters during the 5 full days of the FPRS 14th National, and first International Meeting June 5 through 9.

The technical program, which includes 19 sessions, will feature 57 papers and a number of panel discussions. The second annual FPRS "Honorarium" lecture will be presented by Dr. Alfred J. Stamm, known internationally as "Mr. Wood Stabilization."

Jenkins

Harrar

R. H. Berry

First Day Events

FPRS activities on Sunday will include meetings of the Executive Board, the Tellers Committee, the Membership and Publications Committees, as well as a Press Reception, and the FPRS Eastern Canada Host Section Reception, to which all registrants and their families are invited.

"Honorarium" Lecture

The Technical Program, which was chaired by R. H. Berry, will begin Monday morning, starting off with the General Session and welcoming messages by the Mayor of Montreal, FPRS President E. S. Harrar, and Col. John H. Jenkins, Director of the Canadian Forest Products Laboratory. At this session, Dr. Stamm will give the "Honorarium" lecture, "Fundamentals of Moisture Movement in Wood."

Hogren

Koellisch

Awards Presented

The Eleventh Annual "Wood Award" and the Hitchcock Research Grant will be presented during the General Technical Session. The "Wood Award" is a competition open to graduate students in North American colleges, and is sponsored by Wood and Wood Products Magazine, Chicago. The Hitchcock Grant is sponsored by Hitchcock's Wood Working Digest, Wheaton, Ill., to recognize outstanding research and/or career accomplishments. The "Wood Award" will be presented by Jack Koellisch, Editor and Manager, Wood and Wood Products. The Hitchcock Grant will be presented by Vincent Hogren, Executive Vice-President, Hitchcock Publishing Company.

The Hon. Chevrier Speaks at Official Luncheon

The Honorable Lionel Chevrier will address the 1960 FPRS Official Luncheon on June 7. The subject of his talk will be "The St. Lawrence Seaway—Its Impact Upon the Economy After the First Season of Operation."

Results of the FPRS elections will be announced at the Society's Annual Business meeting to follow the General Session.

Business and Committee Meetings

On Monday evening, the Section Officers Advisory Committee will meet in the Chaudiere Room, and the Division Officers Advisory Committee will meet in the Harricana Room. The meetings are scheduled for 7:30 to 9:30 p.m.

Wednesday afternoon, from 2:00 to 5:00 p.m. has been reserved for the business meetings of the 14 Subject Matter Divisions. There will be no technical sessions held at this time, and registrants are urged to "sit in" on the Division meetings of their choice.

SWST Meeting

The Society of Wood Science and Technology (formerly the American Institute of Wood Engineering) will again hold its annual business meeting and technical sessions in conjunction with the FPRS National Meeting. The meeting, which is open to all registrants, is scheduled for 7:00 p.m. Tuesday in the Peribonca Room.

Social Activities

Special features of this year's Meeting will include the Paul Bunyan Cocktail Hour, sponsored by 50 Canadian and U.S. wood industry suppliers and wood products manufacturers, on Wednesday, followed by the FPRS Banquet. Besides the feast, there will be entertainment for registrants and their families; dancing in LeGrand Salon will last until 1 a.m.

Plans for the Ladies

The ladies will be well taken care of during their stay in cosmopolitan Montreal. Included in the plans for them is a special Ladies Coffee Hour on Monday morning, a tour of Montreal for mothers and children Monday afternoon, a breakfast on Tuesday morning, and a Ladies Luncheon and Fashion Preview Wednesday noon, featuring designs by Raoul-Jean Foure.

National Meeting Steering Committee: Standing, left to right, E. A. Thompson, R. F. DeGrace, G. S. Billington; seated, D. K. Saunders, General Chairman, and P. R. LeSage

TECHNICAL PROGRAM

SESSION 1

GENERAL

Monday, June 6, 8:45–11:30 a.m.
Marquette and Jolliet Rooms

Presiding Chairman: Dr. E. S. Harrar, Duke University, Durham, N. C. and President of the FPRS.

"FPRS Honorarium Lecture," sponsored by the FPRS Midwest Section.

"Fundamentals of Moisture Movement in Wood" by Dr. A. J. Stamm, School of Forestry, North Carolina State College, Raleigh, North Carolina.

Eleventh Annual "Wood Award". Presentation by Jack Koellisch, Editor & Manager, Wood and Wood Products Magazine, Chicago.

Announcement of "Hitchcock Research Grant" to recognize outstanding research and/or career accomplishment. Presented by Vince Hogren, Hitchcock's Woodworking Digest, Wheaton, Ill.

Eastern Canadian Student Awards, presented by FPRS Eastern Canadian Section.

Stamm

Bescher

SESSION 2

WOOD PRESERVATION

Monday, June 6, 2:00–4:30 p.m., Harricana Room

Presiding Chairman, R. H. Bescher, Koppers Company, Inc., Pittsburgh 19, Pa., and Past-President FPRS.

"Quality Control by Toluene Extraction in Procurement of Creosote Marine Piling," by Monie S. Hudson, Consulting Chemist, Spartanburg, S.C.

"Weathering of Creosote During Exposure in ¾-inch Pine Stakes," S. W. Leach, and T. W. Smeal, U.S. Steel Corporation, Trafford, Pennsylvania.
"Creosote-Pentachlorophenol Solution—A Fortified Wood Preservative For Southern Pine Poles," G. Q. Lumsden, Bell Tel. Labs., Inc. Murray Hill, N.J.
"Wood Preservative Test Data as a Guide in Establishing Customer Specifications," H. A. Huber and Ralph M. Gooch, Dow Chemical Company, Midland, Mich.
"Fire-Protected Wood in the Building Code," R. F. DeGrace, Canadian Inst. of Timber Construction, Ottawa, Ont., Can.

Kner

Lewis

SESSION 3
PACKAGING

Monday, June 6, 2:00–4:30 p.m., Chandler Room

Program Chairman: Karl Bollerslev, Boise Cascade Corporation, Boise, Idaho
"Wood's Future in the Packaging Industry," R. S. Kurtenacker, USFPL, Madison.
"Wood as a Protective Medium in Large Packages," by Frank A. Gilhooley, General Electric Co., Schenectady, N. Y.
"Packaging Designed for the 60's," Albert Kner, Container Corp. of America, Chicago, Ill.

Perry

Canty

SESSION 4
CHEMICAL UTILIZATION

Monday, June 6, 2:00–4:30 p.m., Richelieu Room

Presiding Chairman, F. G. Perry, Jr.; Recorder, Mrs. Claire Canty, A. D. Little Company, 30 Memorial Drive (Acorn Park) Cambridge, Massachusetts.
"Use of Sawdust in Continuous Pulping," by Robert C. Linkhart and Thomas Tudder, Potlatch Forests, Inc., Lewiston, Idaho.
"New Uses of Wood Floor in Rigid Polyurethane Foam," by Burton Wilner, Wilner Wood Products Co., Norway, Maine, and Joseph Shulman, Arthur D. Little, Inc., Cambridge, Mass.
"Wood Carbonization in Small Kilns," P. H. Lane, Lake States Forest Experiment Station.

Marra

Mottet

SESSION 5
WOOD COMPOSITION BOARD "A"

Monday, June 6, 2:00–4:30 p.m., Matapedia Room

Presiding Chairman: A. L. Mottet, Recorder, R. W. Young, Long-Bell Div. International Paper Co., Longview, Wash.
Debate on End-Use Approach vs. Properties-Class Approach to Particle Board Standards.
"Advantages of the End-Use Approach to Particle Board Standards," James Hamilton, Mich. College of Mining & Technology, Houghton, Mich.; and Dr. George Marra, Washington State Inst. of Technology, Pullman, Washington.
"Advantages of the Properties Classification Approach to Particle Board Standards," Wayne Lewis, USFPL, Madison, Wis.; and E. Sigurd Johnson, Professor, North Carolina State College, Raleigh, N.C.

Hamilton

McMillin

SESSION 6
WOOD MACHINING

Tuesday, June 7, 8:45–11:30 a.m., Richelieu Room

Presiding Chairman, C. P. Berolzheimer, Calif. Cedar Products Co., Stockton, Calif. Recorder: Charles McMillin, American Machine & Foundry Co., Stamford, Conn.
"Fundamental Aspects of Wood Machining," William McKenzie, Univ. of Michigan, (on leave from FPL, Melbourne, Australia).
"Stress Analysis and the Development of an Experimental Circular Saw-Blade," J. S. Johnston, FPLC, Ottawa.
"Russian Motion Picture on Machining," narrated by Richard Perkins, N.Y. State College of Forestry, Syracuse, N.Y.
"Pendulum Cutting Test Standardization and Pertinent Cutting Fundamentals," (by title only) L. H. Reineke, USFPL, Madison, Wis.
"World Reports on Wood Machining," by Charles McMillin, American Machine and Foundry Co., Stamford, Conn.

Lubeck

SESSION 7
WOOD FINISHING

Tuesday, June 7, 2:30–5:30 p.m., Peribonca Room

Presiding Chairman, N. C. Hatcher, Jr., Drexel Furniture Co., Drexel, N. C. Recorder: Donald G. Lubeck, Hammond Organ Co., Chicago, Ill.
"Research on Wood Finishes," B. G. Brand, L. J. Nowacki, H. N. Johnston, Battelle Memorial Institute, Columbus, Ohio.
"Wood Finishes—How Good Are They?" J. A. Hager, Grand Rapids Varnish Corp., Grand Rapids, Mich.
"Production Finishing Problems," G. M. Hill, Drexel Furniture Company, Drexel, N.C.

Gregory

Saeman

SESSION 8
CHEMICAL UTILIZATION "B"

Tuesday, June 7, 8:45–11:30 a.m., Bersimis Room

Presiding Chairman: Dr. A. S. Gregory, Weyerhaeuser Co., Longview, Wash. and Dr. J. F. Saeman, USFPL, Madison, Wis.
"Use of Bark Extracts in Cold Setting Waterproof Adhesives for Wood." Dr. Franklin W. Herrick and Dr. Romeo J. Conca, Rayonier, Inc., Shelton, Wash.
"Commercial Applications of Lignosulfinate," Ross L. Robinson, Lignosols Chemicals, Ltd. Quebec, Can.
Conca, Rayonier, Inc., Shelton, Wash.
"Current Activities on the Production of Chemicals From Wood in Japan," Kenjiro Takubo, Japan Forest Experiment Station, Meguro, Tokyo.

Blomquist

Northcott

SESSION 9
GLUES AND GLUING "A"

Tuesday, June 7, 2:30–5:30 p.m., Richelieu Room

Presiding Chairman: Dr. Ben S. Bryant, College of Forestry, University of Washington.
"Predicting Plywood Bond Durability," Philip Northcott, FPLC, Vancouver.
"Studies of Rubber-Base Adhesives for Wood Gluing," R. F. Blomquist and Warren Olson, USFPL, Madison, Wis.
"The Effect of the Wettability of Wood on the Glue Line Behavior of Two Urea Resin Adhesives," H. G. Freeman and F. F. Wangaard, Yale Univ. School of Forestry, New Haven, Conn.
"Types of Suitable Adhesives and Gluing ing Procedures for Fire-Retardant-Treated Wood," Leonard A. Ropella, Roddis Plywood Corp., Marshfield, Wis.

Olson

Mater

SESSION 10
LUMBER MANUFACTURING

Tuesday, June 7, 2:30–5:30 p.m., Peribonca Room

Presiding Chairman, M. H. Mater, Mater Engineering, Corvallis, Ore. Recorder, Paul Heller, Mgr., Pacific Pine Lumber Co., New Westminster, B. C., Canada, Panel Moderator, Col. J. H. Jenkins, Director, FPL of

Canada, Department of Northern Affairs and National Resources, Ottawa, Ontario, Canada.
"The Future of the Softwood Lumber Industry in Eastern Canada," Frank Rook, President, Pembroke Shoot Mills, Pembroke, Ontario, Canada.
"Economics of a Small Hardwood Sawmill," Don Cuppett, Union Carbide Chemicals Co., Charleston, W. Virginia.
"The Future of Hardwood Industry in Eastern Canada and Northeastern Canada," George French, Hay & Co., Ltd., Woodstock, Ontario, Canada.
"Cost Reduction in Lumber Handling," J. R. Bemis, Ozan Lumber Co., Prescott, Ark.

Lloyd

Garratt

SESSION 11
MERCHANDISING

Tuesday, June 7, 2:30–5:30 p.m., Bersimis Room

Presiding Chairman, Prof. William Lloyd, Dept. of Forestry, Michigan State Univ., East Lansing, Mich.
Recorder: G. H. Smith, State College of Forestry, Syracuse University.
"Canada Promotes Wood," Cleve Edgett, Manager, Canadian Wood Dvlpmt. Council.
"Wood Promotion in the U.S.," Jerry Prange, Technical Director, National Lumber Manufacturer's Assn., Washington, D.C.

Bryant

SESSION 12
GLUES & GLUING AND VENEER AND PLYWOOD

Wednesday, June 8, 8:30–11:30 a.m., Peribonca Room

Presiding Chairman, Prof. B. S. Bryant, College of Forestry, Univ. of Washington, Seattle.
Recorder: Phil Northcott, Forest Products Laboratories of Canada, Vancouver, B.C.
"Automating Glue Spreading and Lay-up," Charles A. Herstrom, Industrial Engineering and Contracting Company, Portland, Oregon; and Ralph Sullivan, Washington Iron Works, Seattle, Washington.
"Automating Possibilities in the Plywood Plant," Henry Preusser, American Marietta Co., Seattle, Wash.
"Automating Possibilities with Dry Film Glue Line," R. K. Stensrud, Technical Div., Reichhold Chemicals, Inc., Seattle, Wash.

SESSION 13
LOGGING

Wednesday, June 8, 8:30–11:30 a.m., Richelieu Room

Presiding Chairman, J. A. Doyle, FPL of Canada, Ottawa. Recorder: W. W. Calvert, FPL of Canada, Ottawa.
"Water Spraying to Protect Hardwood Logs from Stain and Decay," Paul H. Lane, Lake States Forest Exp. Sta., Wausau, Wis. and Theodore C. Scheffer, USFPI, Madison, Wis.
"The Development of a Logging Mechanization Program by the Quebec North Shore Paper Co., S. J. Simons, North Shore Paper Co., Baie Comeau, Quebec, Canada.
"The Transport of Pulpwood Chips in Pipelines," D. R. Elliott, Pulp and Paper Research Inst. of Can.
"The Integrated Utilization of Southern Pine," T. N. Baker.

Ellis

Fleischer

SESSION 14
INDUSTRIAL-EDUCATION

Wednesday, June 8, 8:30–11:30 a.m., Bersimis Room

Presiding Chairman, Dr. Everett Ellis, Univ. of Michigan, Ann Arbor.
Recorder: Dr. R. N. Jorgensen, Penn State University.
Panel I: "Vocational Training for Wood Technology," E. Sigurd Johnson, N. C. State College, Raleigh, N. C.
"Fundamental or Basic Approach in Training for Wood Technology," Dr. H. O. Fleischer, USFPL, Madison, Wis.
"The Wood Technology Curriculum in the Forestry School," Dr. George Garratt, Dean, Yale School of Forestry, New Haven, Conn.
"Where does Wood Technology Training Belong?", Dr. Alex Panshin, Michigan State University, E. Lansing, Mich.
Panel 2: "Relation of the National 'Wood Promotion Program' to Education Training Program," Paul R. Beattie, NLMA, Washington, D. C.

Roberts

Booth

SESSION 15
WOOD COMPOSITION BOARD "B"

Thursday, June 9, 9:30–11:30 a.m., MacKenzie Room

Presiding Chairman, J. R. Roberts, U. S. Gypsum Corporation, Palatine, Ill.
Recorder: C. C. Booth, Borden Development Laboratory, Bainbridge, New York.
"Significance of Recent Developments in the Production and Use of Hardboard from the Mill Manager's Point of View," O. B. Eustis, Hardboard Plant, Abitibi Corp., Alpena, Mich.
"The Emerite Process of Hardwood and Semi-Hardboard Manufacture," S. Hunter W. Brooks, Emerite Corporation, Jackson, Miss.
"Insulating Board in Canada," Claude S. Goyder, International Panel Boards Ltd., Montreal, Quebec, Canada.
"Exterior Durability of Hardboard," Edward T. Ruffin, Masonite Corp., Laurel, Mississippi.

Stillinger

SESSION 16
QUALITY CONTROL

Thursday, June 9, 9:00–11:30 a.m., Richelieu Room

Presiding Chairman, Dr. J. R. Stillinger, Cascades Plywood Corp., Lebanon, Ore.
Recorder: G. W. Smith, North Carolina State College.
"Work Sampling Method—In Application to the Logging Industry," Gilbert Tardif, Quebec North Shore Paper Co., Quebec, Canada.
"Measurement of Machine Capabilities," Edward R. Hansen, Hamilton Mfg. Co., Two Rivers, Wis.
"Linear Programming in Lumber Production," Norman D. Jackson, Univ. of West Va., Morgantown, W. Va.
"Effective Use of a Computer—A Case Study," B. C. Borden, International Business Machines Co., Ltd., Toronto, Ont., Canada.

SESSION 17
WOOD DRYING

Thursday, June 9, 9:00–11:30 a.m., Peribonca Room

Presiding Chairman, R. S. Millett, FPL of Canada, Ottawa.
"The Moisture Content of Building Structural Members in Situ," W. C. Hopkins, La. State Univ., College of Ag., Baton Rouge 3, La.
"Study of Lumber Drying & Quality Control of Moisture Content in Kiln Dried Lumber," Harvey H. Smith, Pacific Southwest Range & Forest Experiment Station, Berkeley, Cal., and John R. Dittman, Winton Lumber Co., Martell, California.
"Fundamentals of the Drying of Wood," Dr. A. J. Stamm, N. C. State College, Raleigh, N. C.
"Application of Kiln Drying to the Entire Lumbering and Woodworking Industries," G. Billington, Moore Dry Kiln Co. of Can., Brampton, Ont.
"Longitudinal Case-Hardening in Lumber," Dr. Stephen Preston, U. of Mich., Ann Arbor.
Added Feature: Informal discussion on research at FPLC, Ottawa, on kiln-drying of white pine as affected by chemical brown stain and moisture pockets.

Smith

Turner

SESSION 18
WOOD COMPOSITION BOARD "C"

Thursday, June 9, 2:00–4:30 p.m., Mackenzie Room

Presiding Chairman, Kjell Stordalen, Wynnewood Products Corp., Jacksonville, Texas.

Recorder, Dr. Dale Turner, Masonite Corp., Laurel, Miss.

"Show-through of Particle Board Cores as Evaluated by a New Technique," Bruce Heebink, USFPL, Madison, Wis.

"Veneer Checking on Particle Board," Dr. M. M. Yan, Supervisor, Abitibi Power & Paper Co., Sault Ste. Marie, Ontario, Canada, and William G. Lang, Abitibi Co., Toronto, Canada.

"European Development of Particle Board Standards & Testing Methods," Dr. E. Plath, Res. Inst. for Woodworking Materials & Wood Glues, Karlsruhe, Germany.

Groah

Lutz

SESSION 19

VENEER & PLYWOOD

Thursday, June 9, 2:00–4:30 p.m., Richelieu Room

Presiding Chairman, J. L. Lutz, USFPL, Madison, Wis.

"New Plywood Uses Developed by Structural Research," David Countryman, DFPA, Tacoma, Wash.

"Commercial Standards for Hardwood Plywood Products," William Groah, Hardwood Plywood Institute, Arlington, Va.

"Linear Programming in the Plywood Industry," Ernest Koenigsberg, Touche, Ross, Bailey & Smart, Certified Public Accountants.

Six Plant Tours Planned for Montreal Meeting

Six interesting plant tours have been arranged for at the 14th National Meeting in Montreal. Ranging in distance from 5 to 115 miles from the Queen Elizabeth Hotel, the tours have been scheduled for June 9 and 10. Departure hour and final details will be available at the registration desk during the meeting. Transportation will be provided with registration.

Eleven industries are cooperating on the program, including furniture manufacturers, sawmill machinery manufacturers, veneer and plywood producers, and the largest hardwood flooring plant in Canada. An interesting highlight of one of the tours will be a visit to the St. Lawrence Seaway Locks. The tours, plants to be visited, and the hosts are listed below.

Tour	Destination	Plant	Host
1	Ville St-Pierre	Arborite Co. of Canada	Marcel Roy
	Beauharnois	Hydro-Quebec	Jean-P. Marion
2	Lachute	Ayers Wood Products	Jacques Bédard
	Pointe Claire	Pulp & Paper Institute of Canada	Mr. Bennett
3	Montreal	Canada Flooring	A. Clermont
	Ste. Thérèse	Commonwealth Plywood	S. D. Warren
4	Victoriaville	Victoriaville Furniture	F. E. Alain
	Plessisville	Forano Limited	Guy Lemay
5	Cowansville	Viles Furniture	K. L. Elvidge
6	Louiseville	Laminated Structure	Paul Vallières
	Sorel, Que.	Wood Preservation Inc.	M. Drolat

47 Companies to Sponsor Paul Bunyan Hour

Forty-seven wood producers and wood-industry suppliers have contributed as hosts and sponsors of the traditional Paul Bunyan Hour at the 14th National Meeting in Montreal.

Sponsoring firms will be hosts to all attendees and their families Wednesday evening from 6:30 to 7:30 p.m. in the imposing Galerie I of the Queen Elisabeth, Hotel, prior to the FPRS Annual Banquet.

The sponsoring firms as of May 1 are:

American Cyanamid Company
New York, New York

American Manufacturing Company
Tacoma, Washington

American Marietta Company
Seattle, Washington

American Sheet Metal Works, Inc.
Waterbury, Connecticut

W. L. Ballentine Co., Ltd.
Toronto, Ontario, Canada

Behr-Manning Company
Troy, New York

Black Brothers
Mendota, Illinois

Canadian SKF Company, Ltd.
Scarboro, Ontario

Catalin Corporation of America
New York, New York

Chain Belt Company
Milwaukee, Wisconsin

Chapman Chemical Company
Memphis, Tennessee

Collins Pine Company
Chester, California

Decar Plastic Corporation
Middleton, Wisconsin

Diamond National Corporation
New York, New York

J. T. Donnelly Machine Co., Ltd.
Toronto, Ontario

Forano, Ltd.
Montreal, Quebec

Gamble Brothers
Louisville, Kentucky

Hitchcock's Wood Working Digest
Wheaton, Illinois

Hugh C. McLean
Don Mills, Ontario

International Harvester Co., of Canada, Ltd.
Hamilton, Ontario

Koppers Company, Inc.
Pittsburgh, Pennsylvania

Masonite Corporation
Chicago, Illinois

Mattison Machine Works—Greenlee Bros. & Co.

Monetary Times Publishing Company
Toronto, Ontario

Moore Dry Kiln Company of Canada, Ltd.
Brampton, Ontario, Canada

National Casein Company
Chicago, Illinois

National Lumber Manufacturer's Association
Washington, D. C.

Nelsonite Chemical Products, Inc.
Grand Rapids, Michigan

Osmose Wood Preserving Company of Canada
Outremont, Quebec

Perkins Glue Company, Ltd.
Kitchener, Ontario

Potlatch Forests, Inc.
Lewiston, Idaho

Preston Woodworking Machinery Company
Preston, Ontario

Rader Pneumatics, Inc.
Portland, Oregon

Reichhold Cemicals of Canada, Ltd.
Toronto, Ontario

Scott Lumber Company, Inc.
Burney, California

Sel-Set Machinery Corporation
Salem, Oregon

Simpson Timber Co.

Ralph L. Smith Lumber Company
Anderson, California

The Carborundum Company
Niagara Falls, New York

The Coe Manufacturing Company
Painesville, Ohio

The Crossett Company
Crossett, Arkansas

The Lilly Company
High Point, North Carolina

The Pacific Lumber Company
Chicago, Illinois

U. S. Plywood Corporation
New York, New York

West Coast Lumbermen's Assn.

Silvatek Division, Weyerhaeuser Company
Tacoma, Washington

Wilco Machine Works, Inc.
Memphis, Tennessee

Bowater Hardboard Plant

Catawba, S. C.—Production of smooth-on-both-sides hardboard at the new $7,000,000 plant of Bowater Board Company, Catawba, S. C., is scheduled to get underway early next month, according to John G. Robinson, mill manager.

The new plant, which will be the first hardboard mill in the eastern part of the country, has been designed to produce 160,000,000 square feet of hardboard a year, with initial production going to the furniture industry.

Bowater Board will be manufactured by air-or-dry-process, which produces a smooth-on-both-sides characteristic, and other qualities expected to be particularly attractive to the furniture industry. The air process of manufacturing hardboard utilizes high velocity air to blow chips and wood fibers used in the manufacture of the board, instead of water which is used by most manufacturers.

The mill will have the fastest production cycle of any hardboard plant in the world —producing 160-million square feet annually, based on the standard ⅛ inch basis. Daily production capacity of the Bowater Board plant soon will reach 500,000 square feet daily, utilizing 1,000 cords of wood a week. The plant will have 125 employees with an estimated payroll of $500,000 during the opening stages of the operation.

Meet Your Next FPRS President . . . RAYMOND H. BERRY

Raymond H. Berry, dynamic and versatile Vice-President and General Manager of Scott Lumber Co., Inc., Burney, California, will receive the presidential gavel of office from outgoing president, E. S. "Scotty" Harrar, June 7 at the Official Luncheon of the 14th National Meeting of the Forest Products Research Society in Montreal, Canada.

As Mr. Berry, "Ray" to his friends and associates in FPRS, receives the official symbol of office, it will climax more than 12 years of active interest and dedicated service in the Society.

He was designated company representative in FPRS activities when his organization, the Scott Lumber Co., became a supporting member April 23, 1948, a brief 9 months after the Society was founded, and he has maintained that position since.

Served in Many Capacities

He was active in the formation of the Northern California Section, and in 1950 served as Chairman of the Section. For several years he was Trustee of its Board of Directors. In 1955, he was elected Southwest Region Board member and represented that area on the National Executive Board until 1958, when he was elected Vice-President.

He has served on numerous committees for the Board. Some of his outstanding assignments have been: Chairman of the Fund Raising Committee for the National Executive Office in Madison; coordinator of the 14 Subject Matter Divisions; General Chairman of the highly successful 13th National Meeting in San Francisco; and this year's Chairman in charge of the technical program at Montreal.

Liberal "Apprenticeship"

Although he has been associated with the forest products industries for 24 years and active in the Society for at least half that time, Ray has had a most unusual apprenticeship for a lumber operator. A graduate of Yale College (Class of 1920) where he majored in psychology and minored in sociology, of Yale Law School ('24) and with a year's work at the Sorbonne in Paris, he practiced law successfully in Newark, New Jersey for 11 years before he knew there was a difference between Ponderosa Pine and Douglas-fir.

His most notable legal case was one in which there has recently been a revival of interest, because of its subject matter. He conducted the celebrated "Radium Cases" of the late 1920's, securing settlements from employing companies for girl workers who had become cancer victims through the use of radioactive paints in painting watch dials. This is the earliest instance known of mass injury from radio-activity and the medical records of the victims have recently been re-examined by government agencies studying the possibilities of radiation effects on the population. Berry's well-kept record of the cases was of considerable value in this study.

Thawed a Frozen Asset

He was introduced to the lumber business through his law practice. Clients of his were owners of large timber stands in Shasta County, California, which had been considered inaccessible before the opening of paved roads and the advent of truck logging and the big "cats." In 1936, in the heart of the depression, with pine stumpage selling for $2 thousand and fir at 50¢ (and few buyers), he went West to investigate the possibility of making a liquid asset for his clients out of an apparently frozen one. At the end of a few years of complex negotiations and mill-building, he found himself (to his considerable surprise) a director, stockholder, and general manager of Scott Lumber Company, Inc., which proceeded to become one of the best-operated and best known medium-sized lumber operations in the West.

Within the past 10 years, under Berry's management, the Scott Lumber Company has taken advantage of fields opened up by research to add other products to the quality lumber for which it has long had a fine reputation. The mill now produces wood chips for pulp and paper plants, and is marketing several bark products —notably Scott's FERTIMULCH, a soil conditioner made of ground bark which is composted for 6 months in the open air and sold in bulk and in bags for use in home gardens and also in large ranching and nursery operations. The burner, that outmoded sign of the old "cut out and get out" lumber era, was abolished at Scott in 1957, and research is under way to make still further use in finished products of what used to be "burner waste."

Active in WPA, NLMA

The Western Pine Association and the National Lumber Manufacturers Association have also been fields of activity for Ray, who has been Chairman of the WPA District 6 Safety Committee for several years during which the District has established an excellent safety record, and is serving on the Traffic and Timber Appraisal groups of that organization, as well as on its Board of Directors. He is also Chairman of the NLMA Special Committee on Education, and is an Alternate Director of the Association.

Family and Community

Ray and his wife, Justine, have four daughters anld eight grandchildren. They live at Long Valley Ranch near Burney, the town where the Scott mill is located. The ranch house is appropriately shaded by a large grove of Ponderosa Pines of the same type that furnish the raw material for many Scott products.

He is active in community affairs in Burney, being President of the local bank and having been Chairman of the Board of Trustees of the Burney Presbyterian Church from 1949 through 1956. He is a conservaitve Republican, who represents the District on the Shasta County Central Committee of the party. He is also a leading exponent of air travel, having logged nearly a million and a half air miles in the past 20 years on transcontinental and trans-oceanic flights.

Keeps Busy in Leisure

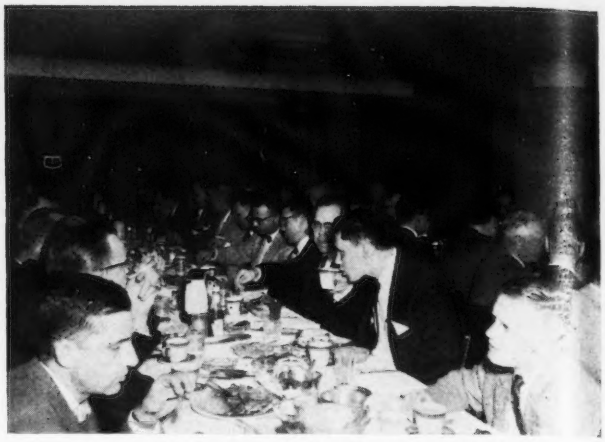
As a boy, Ray studied music with aspirations to the career of a concert pianist, but his activities in the law and in lumber manufacturing have prevented that form of fulfillment. He still, however, plays both piano and organ for his own and other's entertainment. He is a powerboat enthusiast and a dedicated duck-hunter, for which sports he has ideal facilities in the lakes and waterways of his home county of Shasta, which are a mecca for waterfowl during the fall and early winter. He likewise plays a powerful game of tennis and is an active member of tennis clubs on both Coasts of the United States.

New Trustees Appointed For Michigan State U. School of Packaging

Recently appointed to the Michigan State University School of Packaging Foundation, Inc., were Mr. L. A. Curtis, President, Package Machinery Company, East Longmeadow, Massachusetts; Mr. William W. Finn, Vice President, Container Division, St. Regis Paper Company, Chicago, Illinois and Mr. J. F. Mitchell, Operating Manager, Service Parts and Accessories Sup. Division, Chrysler Corporation, Detroit, Michigan.

The School of Packaging Foundation, Inc. was organized in 1957 to raise funds for a new School of Packaging building on Michigan State University's East Lansing campus. The Foundation recognizes the vital need, in American industry today, of personnel thoroughly trained in the increasingly complex field of modern packaging technology.

For further information write Mr. H. G. Walter, Executive Director, School of Packaging Foundation, Inc., Michigan State University, 2918 North Kenneth Avenue, Chicago 41, Illinois.



UPPER MISSISSIPPI VALLEY SECTION MEETING: At speakers' table, left to right, Clarence Maddy, Assistant to Mayor of Duluth; Jack Koellisch, Editor & Manager of Wood and Wood Products; Steve Wise, Program Chairman; Wayne Meek, Section Chairman; Frank Kaufert, Past-President of FPRS. Second photo. 70 members and guests enjoyed an excellent banquet and entertainment at the Flame in Duluth.

U. Mississippi Valley to Back National Forest Products Week

A highly successful spring meeting of the Upper Mississippi Valley attracted 70 members and guests to Duluth, Minnesota for a two-day session April 28 and 29.

The program was concluded with a report by Section Chairman Wayne Meek that the next meeting of the Section would be held October 21–22 to coincide with National Forest Products Week.

Highlights of the program, which was headed by Section Secretary Steve Wise, of Wood Conversion Co., were well organized tours to nearby wood industries and a banquet at Duluth's famous FLAME, with Jack Koellisch, Editor & Manager of Wood & Wood Products as guest speaker.

The plant tours included visits to: Diamond National Corp., Cloquet, Minn., manufacturers of wood matches and match boxes; Wood Conversion Co., Cloquet, Minn., manufacturers of fiberboards, blanket insulation, cushioning materials, and accoustic tiles; and, Superwood Corp., Duluth, producers of hardboard and tempered hardboard.

Thursday evening registrants were guests of Superwood Corp. and the Wood Conversion Co. at the traditional Paul Bunyan Hour.

At the banquet, where he was introduced by Frank Kaufert, Past-President of FPRS, Koellisch, an initiatior and outspoken champion for National Forest Products Week, urged the Section members and guests to take an active part in this promotion in their own communities.

"Top-level support is coming from a majority of the organizations and associations of the forest products industries," he reported, "but there is an urgent need for support and activity at the grass-roots level."

He urged the group to form committees for their city, town, or community and to begin planning now for a hard-hitting public relations and promotional program during the week of October 16–22.

Here are a few of the points he enumerated: 1) Cooperate with the Chamber of Commerce on special dinners honoring the forest industries; 2) Plan special issues for your local newpapers, radio, and TV; 3) Supply wood-industry speakers for the service and fraternal clubs; 4) Urge nearby forest industries to hold open house; 5) Have local merchants install special window displays; 6) Sponsor contests in schools; 7) Have a forest products parade and fair.

"There is no limit to the ideas and action you can initiate," he said, "but the time to get started is now."

U. S. Host to Fifth World Forestry Congress

Two thousand forestry experts from more than 50 nations will meet for 2 weeks in Seattle, Wash., starting Aug. 29, for the Fifth World Forestry Congress.

This international meeting of forestry authorities—many of whom are world famous—is the first Congress for which the United States has been host and the first ever held in the Western Hemisphere.

The foresters will hear 200 authorities speak on every aspect of forestry from surveying virgin timber lands to developing new uses for woods already reaching world markets.

Purpose of the Congress is twofold. It seeks to advance the science and practice of forestry through exchange of information and development of personal associations among the professionals of forestry throughout the world. It seeks also to stimulate and foster international cooperation in the proper development and use of the world's forest resources.

The meeting will be the largest international gathering of foresters ever held. In recognition of its importance, both the United Nations will issue commemorative stamps, and U. S. Post Offices will use special stamp cancellation dies.

The Congress program will cover all major fields of forestry and forest product utilization. Special attention will be given problems of multiple use of forest lands for the integrated production of timber, forage, water, wildlife, and recreation. The program also calls for a review of the status of world forestry in 1960.

During the 2 weeks of daily meetings, exhibits will be displayed of logging and forestry tools, machinery and equipment, and other educational material on forestry and forest conservation.

Participation in the Congress is open to accredited government representatives; scientific, technical and educational organization representatives; and interested individuals associated with the fields of forestry, forest conservation, and forest industry.

NLMA Wood Promotion Booklet Revised

The booklet—"Heres How You and the NWPP Make a Powerful Sales Team for Wood Products," has been newly revised and brought up to date. The 24-page publication was reprinted in order to meet the flood of requests for information on the National Wood Promotion Program from manufacturers, wholesalers, retailers, and other segments of the wood industry.

National Academy of Science Sets Up New Fund for Research

At its meeting in New York on April 4, the Board of Governors of the Building Research Institute, National Academy of Sciences–National Research Council, announced the establishment of a new Building Science Education Fund, to be used for the stimulation of a program for encouraging highly creative people to pursue building research activities in colleges and universities.

Said Milton C. Coon, Jr., BRI executive director, "The BRI Board has appropriated $2,000 from Institute funds to launch this enterprise, one which we feel will have far-reaching effects in encouraging college and university research workers to focus their attention on some of the major problems that need solving in our advance toward better buildings."

The National Academy of Sciences–National Research Council established this fund upon the recommendation of the BRI Board of Governors. The fund will be used to further the goals of the Education Liaison Committee, which has been working closely during the past year with college and university faculty members, in an effort to interest them more actively in research for buildings.

Midwest Section officers met May 6 to lay plans for the Oct. 20–21 Annual Meeting in Madison, Wis. The program will be built around the services of, and in recognition to, the U. S. Forest Products Laboratory, now observing its 50th anniversary of service to industry. Left to right: Jack Koellisch, Don Lubeck, Willard Gullickson, Jim Gill. Second photo: Chairman Bob Archambeault, Secretary Roy Newstadt, Jack Koellisch. Not shown, Treasurer Ken Kimball.

Model of internal-fan dry kiln attracts attendees of U. S. Forest Products Laboratory's 84th kiln-drying demonstration.

USFPL Holds 84th Kiln Drying Demonstration

Forty-two persons, representing various wood industries, received the latest information on equipment and practices used for seasoning of wood, at the 84th Kiln Drying Demonstration of the U. S. Forest Products Laboratory.

The 2-week demonstration that wound up in early April was held as part of the activities marking the Laboratory's golden anniversary year. In addition to the fundamental principles presented, such as shrinkage of wood, kiln operation and drying schedules, special emphasis was placed on helping plants reduce the losses of lumber and the cost of drying it.

The men taking part this year sought answers to specific problems as well as the general information they acquired.

"Never have I had so many questions shot at me so fast and for so long a time," grinned E. F. Rasmussen, who has been directing these demonstrations at the Laboratory since 1946.

"In this demonstration we try to lay a groundwork of fundamentals and then rely on a common sense approach to problems, rather than just memorizing some answers. For our part, we want to see research results put to work. At the same time these practical industry problems guide us in our own approach to research."

Besides the classroom instruction, the men solved practical problems in the use of moisture meters, balances, drying ovens, recording-controlling instruments, and other dry kiln equipment.

Wood Pole Institute, June 15–17, Colorado State University

The Wood Pole Institute, sponsored by the Rural Electrification Administration, Regional Utility Companies, REA Cooperatives, and Colorado State University, will be held at the University in Fort Collins, Colorado, June 15–17.

Research News from Forest Products Labs of Canada

Timber Fastenings Studied

Component parts of a wooden structure may be joined with facility. The ultimate strength and stability of a structure may be governed largely by the design of the joint and the type of the fastening. The Forest Products Laboratories of Canada, Vancouver, Ottawa, have made studies of the holding capacity of numerous types of fastenings.

A timber fastening, is any device which holds two or more pieces of wood together. For maximum strength and durability of service, each device requires that the joint design be adapted to the varying strength properties of wood along and across the grain.

For structural requirements, the main considerations in determining the type of fastening are lumber dimensions, type of loading, loading capacity, fabrication method, and assembly.

The Accelerated Drying of Yellow Birch

A recent publication, "High Temperature Drying of Yellow Birch" by J. L. Ladell, reports on the use of elevated schedules for hardwood lumber or dimension stock. Using temperatures just above the boiling point of water and with intermittent steaming, yellow birch was dried from the green condition in 2 days with little degrade. Collapse in the heartwood was the only significant defect. Comparative static bending and toughness tests indicated that no reduction in these strength properties resulted from drying at high temperatures.

Equilibrium moisture content values were markedly lower for this material which suggests that stablilization may be a practical advantage of elevated temperatures in drying. These, and other data on the high temperature drying of yellow birch are available from the FPLO on request, in either English or French.

Prolonged Heating of Veneer Logs

Proper heat treatment of veneer logs of many hardwood species is essential for the production of veneer of a high quality. The only purpose of the heating process is to increase the temperature of the log to soften or plasticize the wood so that it can be cut tightly and smoothly by the lathe knife. The heat treatment temperature varies considerably from one species to another. Contrary to an opinion sometimes held, prolonged heating of the logs after they have reached the optimum temperature serves no beneficial purpose, and under some circumstances, may have a detrimental effect. Further information on optimum cutting temperatures and heating schedules is available from the Forest Products Laboratories of Canada.

Recent FPLC Publications

The following new publications are available on request from either the Ottawa or Vancouver Laboratory, Forest Products Laboratories of Canada, Forestry Branch, Department of Northern Affairs and National Resources.

Tech. Note #13—The Effect of Compression-Wood on the Mechanical Properties of White Spruce and Red Pine. E. Perem.

V-1027—Some Conversion Factors for British Columbia Forest Products. F. W. Guernsey.

A Vital Responsibility—The FPLC Role in National Specifications. J. H. Jenkins.

Performance Test for Poultry Containers. J. M. Rudnicki.

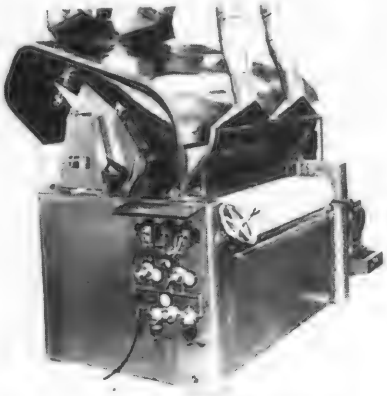
Undercure . . . Casehardening in Plywood. P. L. Northcott, H. G. M. Colbeck, W. V. Hancock and K. C. Shen.

The Air Drying of Lumber in Western Canada. F. W. Guernsey.

NEW PRODUCTS
and Literature

Georgia–Pacific Markets New Marine Plywood

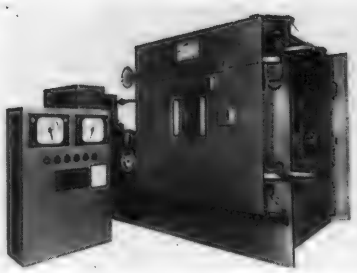
Georgia–Pacific Corporation has developed and marketed a high-performance boat panel of overlaid mahogany plywood. Called GPX Marine Green, the panel has a medium-density resin-fiber overlay said to produce a check-free, highly paintable surface. Literature and samples are available from Georgia–Pacific Corp., Dept. GPX, Equitable Building, Portland 4, Oregon.



New Wide-Belt Sander

A new wide-belt sander that produces accurate thickness tolerances on veneered and solid wood panels and furniture components has been announced by Preston Woodworking Machinery Co., Ltd., Preston, Ontario, Canada. Designated the Preston 1000 Wide Belt Sander, this heavy-duty unit is available in widths up to 50" to meet any plant requirement.

Spring loaded chipbreaker bar and solidly fixed pressure bar hug the cutting circle of the belt to eliminate dubbing and permit short stock sanding. Pieces as short as 10 inches are securely held by this system.



New Test Chamber Has Range of Minus 100° F. to Plus 1000° F.

Extreme range of temperature variations, from —100° F to +1000° F, is now available in this new environmental test chamber just completed by the American Research Corp., Farmington, Conn.

Designed to simulate conditions which might be encountered by outer space vehicles, the chamber produces both high and low temperatures by radiation from all six sides, as well as by convection, thus reproducing true, high altitude conditions completely around the test specimen. In addition, at any temperature and at any altitude up to 150,000 ft., the gradient throughout the chamber can be held as closely at ±5° F. The chamber illustrated has a free test space of 1′ x 1′ x 1′ and is equipped with mechanical refrigeration capable of dissipating a heat load at the rate of 7500 watts at —70° F.

National Casein Increases Laboratory Facilities

An expansion of laboratory facilities at their Riverton, New Jersey plant has been announced by National Casein Company, manufactures of woodworking glues for industry.

A 25 percent increase in testing equipment and a 50 percent increase in laboratory personnel has already been accomplished. Included in the expanded facilities are: (1) A testing device for glue viscosities (2) microscopic apparatus to examine woodwork joints and glues (3) a new high-pressure hot press to enable research for new techniques in producing plywood glues and (4) a miniature lab-size pilot plant which simulates actual plant conditions.

Electric Powered Grapple for Safer Log Handling

A new, electrically actuated log grapple for use on log loaders with either heel or straight type booms, or single-line fixed-crane installations has been announced by R. G. LeTourneau, Inc.

Chart on Nails Shows Types, Sizes, Materials

A new fold-out chart by United Shoe Machinery Corporation displays all the data needed by industrial, service, production, and engineering specialists who specify or work with nails and fastenings. The chart shows all the types of shanks, heads and points for regular nails and for special configurations. Data is based on extensive studies conducted by the U. S. Forest Products Laboratory and on tests by company engineers. Copies are available from Howard Sert Department, United Shoe Machinery Corp., 140 Federal St., Boston 7, M

Redco Announces Magnestat Memory System with Wide Application in Lumber Industry

A simple and rugged magnetic memory system with wide lumber industry applications on grade marking, trim saw control and lumber sorting has been announced by Republic Electric & Development Co. of Seattle. Named the Magnestat Memory System, it provides automated control of grading, sorting, stamping or trimming operations on conveyed materials.

Heart of the Magnestat is a reliable magnetic memory disc turning in synchronization with the product flow. The discords control decisions, made manually by push-button console or automatically by limit switches, as magnetic impressions. A decision can be made at one point in the production line and then stored on the magetic disc to be automatically executed at the proper stage later in the production line. Typical applications of the Magnestat in the lumber field include its use in controlling grade marking equipment to meet new F.H.A. requirements, on saw trimmers, and lumber sorting machinery

Industry Awards Highlight Golden Anniversary of FPL

Madison, Wis.—New trends in research in wood will be spotlighted and past accomplishments mirrored by speakers, exhibits, demonstrations, and industrial achievement awards when the U. S. Forest Products Laboratory's golden anniversary is celebrated here June 2–4.

The 3-day affair will begin with a banquet Thursday, June 2, according to Dr. Howard G. Locke, Laboratory director. Principal speaker will be Ervin L. Peterson, Assistant Secretary of Agriculture in charge of Federal-State relations. Dean George A. Garratt of Yale University's School of Forestry will be toastmaster, and Richard E. Mandle, chief of the U. S. Forest Service, will also speak.

Industry recognition of outstanding research accomplishments will be highlighted by the presentation of several plaques to the federal Laboratory by the Home Manufacturers Association; American Institute of Timber Construction; and Douglas Fir Plywood Association.

The housing award will be in recognition of the federal Laboratory's research that produced the stressed-cover system of panel design and construction now widely used for mass producing factory-built houses. Two history-making houses built at the Laboratory in 1937, and in constant use for offices ever since, were the first full-scale structures designed along stressed-covered principles. George E. Price, president of National Homes, Inc., Lafayette, Ind.—the giant among the Nation's producers of factory-built houses—will make the award on behalf of HMA.

Another uniquely historic building—the first built in the United States with glued laminated arches according to Laboratory-developed research findings—will be recognized by the AITC award. The arches in this building, erected in 1935, triggered an industry that now produces hundreds of millions of dollars worth of glued laminated structural timbers a year.

The plaque recognizing the Laboratory's research on glued laminated timber design and fabrication will be presented by Frank J. Hanrahan, executive vice president of AITC.

The same building will get double-barreled recognition because it also exemplifies the first use of waterproof exterior-type plywood—now widely produced and marketed. When it was erected in 1935, however, all plywood was made of glues that lacked the needed water resistance for outdoor use. Laboratory experts had to set up glue specifications for the producers of the plywood and supervise its production. The plywood on the building's exterior walls remains in excellent condition after a quarter century of service.

W. E. Difford, executive vice president of the Douglas Fir Plywood Association, Tacoma, Wash., will present the Laboratory with a plaque recognizing its pioneering research in this field.

The awards will be presented at ceremonies Friday afternoon, June 3. The Laboratory will be open to invited guests that afternoon and to the general public all day Saturday, June 4.

EMPLOYMENT Opportunities

Positions Offered

E-389—Product Development. Leading redwood operation is expanding its product development section. Opportunity to work in development of mill applied coatings to lumber and plywood, waste utilization, plywood products, hardwood utilization glued products, etc. Prefer man with M.S. or B.S. in wood technology or wood utilization. (May)

E-390—Wanted: Sales Engineer. Self-propelled, creative salesman, with structural engineering degree and experience—as trainee for six months in Seattle, then development of market for a plant in California—for growing components manufacturer. (June)

E-391—Wanted: Sales Manager for Saw Mill Machinery Manufacturer. Man of proven administrative ability to direct northwest sales. Also supervise engineering and customer service. Coordinate efforts of sales engineers. Determine policies and handle top-level customer contacts. Send complete resume of education, experience, salary, references, etc. All replies confidential. Our employees know of this opening. (June)

E-393—State Forest Service in the South has an opening for a qualified Wood Technologist or Forest Utilization Specialist. Recent graduates or men with modest experience in the field acceptable. Applicants must hold Master's Degree, be interested in research work, and capable of working with private industry. Wood utilization experience will be accepted in lieu of educational requirement in exceptional instances. (June)

Employment Wanted

600—Sales, promotion, or public relations position with opportunity for growth and advancement wanted by wood technologist. Experience in sales, technical service, quality control, R & D, plywood and adhesives. B.S. in Forest Products from University of Washington. Prefer West. Age 32, married, 3 children. Resume on request. (June)

605—Young man, single. Will graduate from University of Michigan in June, 1960, with a major in Wood Technology. Second field, Forestry. Would accept employment anywhere, except in the general South. Interested in research, production, management, or sales—in that order. (May)

607—Wood Technology major. Will graduate in June, 1960, from University of Michigan, wants position, preferably in the general West. Second field, Forestry. Is particularly interested in adhesives and particle board, kiln drying, and timber mechanics. (June)

608—Dissatified with present job, Forestry School graduate wants job in Product Development, Production, or of other technical nature. Little or no traveling. (June)

610—Registered Professional Engineer; several degrees; 47; excellent health. Years' experience in design and research of all types of buildings and prefabrication of buildings. Cost and quality conscious, inventive, also experienced as chief engineer and head of design department. Seeks permanent responsible position. (June)

What's New in Technical Publications

Single Copies of the Following Reports are Available Free Upon Request from the Director, U.S. Forest Products Laboratory, Madison 5, Wis.

Report No. 1698, "The U. S. Forest Products Laboratory," is an up-to-date account of the Laboratory's objectives and activities and one of nine new or revised reports recently issued here by the U. S. Forest Products Laboratory, which is observing its golden anniversary this year.

A new report, **"Adhesives and Their Application to Fabrication of Farm Structures," No. 2178,** describes glues and glued-wood products that can be used to construct farm buildings.

The amount of material lost because of inaccuracy in sawing and how to remedy such losses are explained in a new report, **"Volume Loss from Inaccurate Sawing," No. 2174.**

Report No. 2176, "Training Teen-Aged Trees," presents an illustrated account of the problems encountered in growing trees from seedlings to maturity and suggests some corrective measures.

The physiological characteristics of soft-rot fungi and isolation data on over 100 organisms are contained in a report, **"Wood-Attacking Capacities and Physiology of Soft-Rot Fungi," No. 2173.**

Two progress reports, **"Comparison of Wood Preservatives in Mississippi Post Study," No. 1757,** and **"Comparison of Wood Preservatives in Stake Tests," No. 1761,** incorporate the latest research findings and treatments used in these two studies.

Report No. 1964, "Nonplastic Molded Pulp Products," has been revised to include recent information relating to raw materials, equipment, and methods of manufacture of molded pulp items, such as egg cartons, pie plates, florist vases, and toys.

(Professional Card)

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87 NEW OR TRANSFER MEMBERS IN MARCH

Section Officers Please Take Note. We are going to publish each month all of the NEW or Transferred-into-the-Section Members. Please adjust your records, and gear to the most concerted New Membership Activity in FPRS history!

CAROLINA–CHESAPEAKE

W. A. Biggs, Jr., Sonoco Products Co., Hartsville, S. C.
T. B. French, Diamond Ave., Rocky Mount, Virginia.
Hubert L. Person, 610 Oak Haven Dr., Falls Church, Va.
Amos L. Peak, C-5 Raleigh Apt's., Raleigh, N. C.
Alfred Schainholz, Magnolia Street, Forest City, N. C.

EASTERN CANADIAN

R. W. L. Laidlaw, 50 Oak St., Weston, Ontario, Can.
Karl D. Simmerling, P. O. Box 1052, Kirkland Lake, Ontario, Can.

GREAT LAKES

Richard A. Bicknell, 2329 Holiday Dr. S. W., Grand Rapids 9, Mich.
William E. Dalman, Imperial Carving Co., Allegan, Mich.
Norman C. Higgins, 5610 Church Rd., Route 1, Perry, Mich.
Oliver F. Hoag, 300 Webster, N. W., Grand Rapids 4, Mich.
Randall E. Holt, Monical Machinery Co., 2020 Bristol Ave., N. W., Grand Rapids 4, Mich.
Edward A. Koza, 1408 'G' Spartan Vill., E. Lansing, Mich.
W. A. Rifenberg, Jr. The Brunswick Balke Collender Co., Muskegon, Mich.
George D. Schad, Nucraft Furniture Co., 1615 Eastern Ave., S. E., Grand Rapids 7, Mich.
Arnold A. Schwartz, Huntingburg Fabricators, Inc., Huntingburg, Ind.
Stanley L. Warber, Monical Machinery Co., 2020 Bristol Ave., N. W., Grand Rapids 4, Mich.

MID-SOUTH

Deborah Almy, 271 South Bellevue Blvd., Memphis, Tenn.
E. D. Heehs, Box 6832, Memphis, Tenn.
Michael O. Hunt, 606 West Cherry St., Jonesboro, Ark.
Ann G. Humphreys, Humphreys Mills, 34 East Illinois Ave., Memphis, Tenn.
Darrel V. Keller, Apt. 6, 904 N. W. 36 Terrace, Oklahoma City, Okla.
R. R. Milner, Valley Brokers Co., Room 932, Falls Blvd., Memphis, Tenn.
Kenneth W. Rockett, Yale Forestry Camp, Crossett, Ark.
J. E. Shannon, Jr., Shannon Bros. Lbr. Co., 1646 Texas Street, Memphis, Tenn.
Dr. Robert E. Stutz, P. O. Box 3158, Mallory Station, Chapman Chemical Co., Memphis 9, Tenn.
Nipit Sutan–Tanon, Box 6565 University Sta., Baton Rouge, La.
Zeno L. Yeates, 476 South Goodlett, Memphis, Tenn.

MID-WEST

Richard Arney, 1317 Prospect, Webster City, Iowa
Mr. John R. Barney, Motorola Inc., 4545 W. Augusta Blvd., Chicago 51, Ill.
Charles Casteel, 1021 East Walnut St., Columbia, Mo.
Rowland M. Garratt, 2206 S. Chase St., Lombard, Ill.
Frank J. Hoffmann, Frank J. Hoffmann Company, 1737 Howard St., #401, Chicago 26, Ill.
John L. Mace, 746 Miami Pass, Madison, Wis.
J. V. Mills, Sears, Roebuck & Co., 3340 W. Fillmore, Chicago 7, Ill.
Charles Pope, Motorola Inc., 4545 W. Augusta Blvd., Chicago 51, Ill.
Roger Reves, 315 Welch, Ames, Iowa
James G. Schroeder, 1811 Spruce St., Murphysboro, Ill.
Charles Lewis Stayton, 305 West Williams St., Champaign, Ill.

NORTHEAST

Rene Bollengier, 52 Quagnut Dr., Wakefield, R. I.
Collins Pine Company, Attn: Chas. M. Genaux, Star Route, Sheffield, Pa.
Walter H. Davidson, 32 West St., Hadley, Mass.
James P. Fennessey, State University College of Forestry, Syracuse University, Syracuse, N. Y.
George E. French, c/o Rev. E. French, 95 Meadow Ave., Naugatuck, Conn.
Allan F. Gordon, University of Maine, School of Forestry, Orono, Me.
Andrew J. J. Kass, 768 Argyle Rd., North Hills, Pa.
Martin G. Knappe, 309 E. Bettlewood Ave., Oaklyn, N. J.
Paul McCormack, Product Development Engineer, National Starch & Chemical Corp., 1700 W. Front St., Plainfield, N. J.
David P. McKay, R. F. D. #1, Reeds Ferry, N. H.
Theodore F. Michalek, 228 Upson Lane, University Heights, New Brunswick, N. J.
R. A. Moore, Wood Products Engineering Dept., State Univ. College of Forestry Syracuse 10, N. Y.
Robert C. Peterson, State University College of Forestry Syracuse University, Syracuse, N. Y.
Pierce & Stevens Chem. Corp., Attn: Library, 710 Ohio St., Buffalo 3, N. Y.
Charles E. Pottenger, R. D. 3, Campmeeting Rd., Sewickley, Pa.
A. W. Salstrom, Plywood Finish Corp., 133 Sutton St., Brooklyn 22, N. Y.

NORTHERN CALIFORNIA

J. J. Allegretti, Director of Special Products Division, Scott Lumber Co., Inc., Burney (Shasta County), Calif.
Adolphus Andrews, Jr., Pope & Talbot, Inc., 100 Bush St., San Francisco 4, Calif.
Myron Bird, California Saw & Knife Works, 721 Brannan St., San Francisco 3, Calif.
Eugene Lee Bryan, 2893 Ruff Ave., Pinole, Calif.
Ivan R. Vrooman, 2432 'L' Street, Simpson Redwood Co., Eureka, Calif.

OHIO VALLEY

William F. Dwyer, Masonite Corp., 19685 Hilliard Rd., Rocky River 16, Ohio
Thomas C. Habig, The Jasper Corp., P. O. Box 360, Jasper, Ind.
William H. Hoffman, Masonite Corp., 512 Chippewa Dr., P. O. Box 2, Greenville, Ohio
Duane R. Keck, Research & Development Div., The Champion Paper & Fibre Co., Hamilton, Ohio
Arno Lessheim, c/o Hillenbrand Industries, Batesville, Ind.
Richard L. Voss, Masonite Corp., 1255 Forest Court, Cincinnati 15, Ohio
Roy L. Westenfelder, The Carborundum Co., 2025 Rosedale Dr., Indianapolis 27, Ind.

PACIFIC NORTHWEST

W. P. Crooks, S. K. Limited Plywood Div., P. O. Box 390, Kelowna, B. C., Can.
F. W. Fearman, MacMillan & Bloedel Ltd., Can. White Pine Div., Ft. Kinross St., Vancouver, B. C., Can.
Byron L. Foreman, Research Eng., Research Lab. Western Pine Assoc., 7733 S. E. 13th Ave., Portland 2, Ore.
Ross Edward Haffner, 816 Ravenna Blvd., Seattle 15, Wash.
Russell Jones, Kokish P. O., Beaver Grove, B. C., Can.
Cliff G. Moore, 3105–30th Ave., Vernon, B. C., Can.
Leo Nielsen, 2395 W. 7th Pl., Nielsen Saw & Mfg. Co., Eugene, Ore.
Donald W. Pleier, Sec.-Mgr., 4403 White St., Henry–Stuart Bldg., Seattle 1, Wash.
Bernarr E. Welch, Research Lab. Western Pine Assn., 7733 S. E. 13th Ave., Portland 2, Ore.

PACIFIC SOUTHWEST

Ewing Seligman, 242 South Anita Ave., Los Angeles 49, Calif.

ROCKY MOUNTAIN

Adrian C. Godfrey, 7th & Larimer, Hallack & Howard Lbr. Co., Denver 1, Colo.

SOUTHEASTERN

Harold O. Baxter, c/o Ga. Agriculture Extension Service, Athens, Ga.
John F. Bethea, Jr., Soderhamn Machine Manufacturing Co., P. O. Box 927, Talladega, Ala.
Wayne E. French, 322 Inglewood Dr., Savannah, Ga.
J. W. Griffin, Wells Griffin Lumber Co., P. O. Box 1251, Valdosta, Ga.
Clarence Miller, Buckeye Cellulose Corp., Foley, Fla.
Julius Stern, Southern Plywoods, Inc., P. O. Box 448, Greenville, Fla.
Donald D. Stevenson, Chief Forester, The Buckeye Cellulose Corp., Foley, Fla.
William T. Wooden, Route 2, Box 17, Auburn, Ala.

UPPER MISSISSIPPI VALLEY

Guy M. Schaefer, 608 Eleventh St., Minnesota & Ont. Paper Co., International Falls, Minn.

NAMES in the NEWS

Herbert E. Allender has been named assistant to the sales manager of Bowater Board Company, according to J. R. **Hahn,** sales manager. Mr. Allender was formerly associated with the Masonite Corporation in Indiana, Illinois and Georgia.

Appointment of **M. C. Wakefield, Jr.** to the position of sales manager of the Polyco Monomer Department of the Borden Chemical Company, a Division of The Borden Company, has been announced by **C. W. Smith,** general manager.

The Scott Foundation Scholarship award, one of the educational programs of **Scott Paper Co.,** Chester, Pa., has been given to **Donald E. Dau,** a top level University of Wisconsin engineering student from Wausau, Wis.

National Polychemicals, Inc. has appointed **Henry R. Lasman,** Manager of the Organic Chemicals Division, Edward **V. Osberg,** President, said.

Synco Resins, Inc. of Bethel, Conn., announces the election of **J. Whitney MacDonald** as President and General Manager. Mr. MacDonald, who has for the past 6 years been President of Fulford Manufacturing Company of Providence, R. I., has also been a Director of Synco Resins for ten years.

John W. Rankin has been appointed West Coast Product Development Manager of United States Plywood, it was reported by **Gene C. Brewer,** the company's president.

Southwest Forest Industries, Inc. has named **A. J. Wilson** of Wilson Paper Division, Los Angeles, and **Lee B. Zeagler** of Edens–Birch Division, Corrigan, Texas, vice-presidents of the firm, according to **J. B. Edens,** the president.

Henry M. Heitman has been appointed sales engineer for the North Atlantic territory by the "Pop" Rivet Division of United Shoe Machinery Corporation.

Cecil Baltzegar has been named manager of the market research department at Omark Industries, Inc., **Edward P. Skralskis,** Omark general manager, stated.

Cliff Vanderwerker, Jr. president of Victory Carbide Saw & Tool Company of Antioch, Ill. has announced the appointment of **H. J. Howard** as sales manager.

The Evans Products Company has established an annual undergraduate scholarship of $750 and a graduate fellowship of $1500 in forestry at Oregon State College, Corvallis, Oregon, according to **E. S. Evans, Jr.,** president.

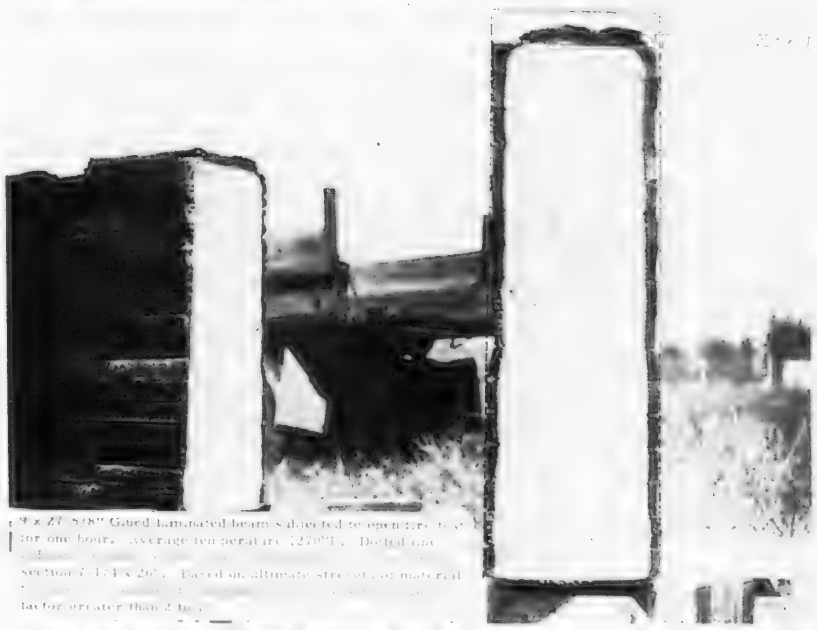
FPRS FOREST PRODUCTS JOURNAL VOL. X, NO. 5 MAY, 1960

ARCHITECTURAL CHARACTERISTICS OF . . .

Glued Laminated Wood

A. E. Oviatt, Jr.
Timber Structures Inc., Portland, Oregon

Contemporary use of laminated wood depends on structural, economic, and aesthetic characteristics. Remarkable design potential results from combining many attributes in a single design. This is the materials essential competitive characteristic.



"HIGHLY RESISTANT TO DESTRUCTION BY FIRE"—Tests by Timber Structures, Inc. and Pittsburgh Testing Laboratories

During the last 10 years, the use of glued laminated timbers in building has grown at a very rapid rate. This increased structural utilization of wood has taken place in a period of active competition from new materials and techniques and in the face of an adequate supply of structural steel. The trend is a substantial triumph of wood technology in placing the natural material of the forests more fully under the control of modern engineering and manufacturing methods. The result has been an improvement of the characteristics of wood for use in construction and the development of predictable and reliable performance standards that have brought the material under more precise engineering control.

All of us are aware, however, that timbers in primitive forms were used in building before recorded history began. The record of history gives continuing evidence of the unique adaptability of wood to the needs of man. Many of the time-proven advantages of wood remain unchanged in the laminated timber, and we must modestly regard recent technical advances as improvements or refinements in a familiar servant. The characteristics of laminated material are the sum of natural and engineered characteristics.

Glued laminated wood has found its readiest acceptance in the architectural field. This fact should suggest that the standards by which it is judged and selected for this use are a little different from the basic engineering standards upon which the selection of a purely functional material for industrial use might be made. Considerably more importance is given to aesthetic and intellectual qualities than is usual for other types of products. An architectural material is a medium of artistic expression as well as a basic building block with physical characteristics. A realization of this fact is essential to full understanding of the growing use of modern timbers.

What are the architectural characteristics of this material which are giving new life to the utilization of structural timbers? A complete answer to this question must consider the natural attributes of wood as well as technological improvements. It must recognize that the architect is a creative artist as well as a builder, capable of integrating several or many desirable characteristics of a versatile material in a single composition. Let us examine singly the important architectural properties of the material and how they lend themselves to full design exploitation.

Structural Properties

Stability: In an architectural sense, a structural material must look stable and be stable. There may be those who hold that the fact of stability is a great deal more important than the appearance of stability. This is true to a degree. However, when we reflect that the architect deals with human emotional reactions as well as mechanics, the appearance requirement is also quite valid. The occupant should not be made uncomfortable by any uncertainties about continued stability, and even the casual observer is emotionally impressed by the degree of apparent integrity of a building. When we consider that beams are usually cambered only for this reason, its importance to the architect can be seen. Large checks due to the drying in place of sawn

The Author: Alfred E. Oviatt, Jr. has a degree in architecture from Yale University and he also participated in special studies at the Yale School of Forestry. He is Executive Assistant at Timber Structures, Inc.

[1] Presented at the Northeast Section Meeting in Worcester, Mass., October 30, 1959.

"CURVED SHAPES OF HIGH STRUCTURAL EFFICIENCY"—University Field House in Missoula, Montana. Brinkman & Lenon, Architects.

timbers are often erroneously taken as evidence of instability. This appearance defect is eliminated in pre-dried laminated timbers.

Natural sawn timbers have long possessed the structural quality of actual stability when designed with adequate allowances for moisture content and natural variability. The advance which has been made in laminating is one of degree and safety, allowing higher dry stresses, controlling variability, and increasing the reliability of engineering prediction. The appearance of stability has been improved by control of surface checking and by building in camber in laminating.

Strength: In an architectural sense, the stress values used in the design of structural materials are of no more than incidental interest. Structural materials are seldom chosen strictly on the basis of strength alone. It can be shown that laminated timbers are about one-third stronger than sawn timbers of equal section, but this fact alone has little bearing on the increased use of the former. Similarly, laminated fir is stronger weight for weight than structural steel, but weaker volume for volume. These comparisons mean almost nothing in architectural selection. Structural materials are chosen for their suitability to the designer's purpose, for safety, permanence, economy, and appearance. It is only necessary that strength be sufficient to carry design loads over any spans for which other materials might be considered, using members of reasonable size. Member sections for laminated timbers are commonly little more over-all than for equivalent steel sections, and may be measurably smaller than for ordinary reinforced concrete.

Manufactured under controlled modern factory conditions, laminated wood is produced to uniform and predictable strength and quality, and is an engineered material of assured structural safety. In this sense, timber has become the equivalent of its engineered metal rivals, and holds some edge over job-site manufactured concrete, whose control and inspection is conducted at a disadvantage.

Fire Resistance: Closely related to design safety is fire-resistance, as it affects both life and property. The heavy timber, "slow-burning", sections characteristic of laminated members are highly resistant to destruction by fire. Students of this problem readily agree that heavy timber sections retain their structural function far longer than do exposed metal sections under similar conditions of heat. Some codes, however, continue to limit the use of timber, and fire rating bureaus continue to penalize it. Code limitations are often based upon the unrealistic concept of "combustibility" as a measure of safety, ignoring the fact that fire hazards are usually a function of the building's contents and finishes rather than its construction. No structural material is fire-proof in an absolute sense. Timbers are slowly consumed by fire, while metals rapidly lose their strength, glass melts, and masonry cracks. Fire resistance is more accurately a function of time rather than method of destruction.

Considerable educational work remains to be done in this field, but encouraging progress has already been made. The American Institute of Timber Construction and National Lumber Manufacturers Association are engaged in major efforts on this problem and it is to be hoped that more realistic evaluations will result. Meanwhile, recent advances in treatment with fire-retardant chemicals have created a break-through against the "combustibility" bogey. Laminated timbers are particularly well adapted to pressure-treating methods such as this since it is possible to obtain excellent impregnation by treating the individual laminations prior to gluing. New formulations have already earned substantial acceptance, and it is believed that it will very shortly be possible to deliver laminated timbers to the job stamped with the underwriters' rating "incombustible". The psychological effect of this on owners and designers may well be far more significant than the actual improvement in resistance to destruction.

The popular notion that wood is deficient in some vague way in its useful life in a structure appears to result from ignorance of its properties. Hundreds of existing examples from history belie this notion. These examples include timber structures many hundreds to over a thousand years old. In point of fact, wood is one of the most durable and permanent of architectural materials when properly designed and adequately maintained. Performance records are necessarily lacking where laminated timbers are concerned, but laboratory tests of adhesives reasonably indicate that timbers suitably bonded will last indefinitely under design exposure conditions.

All materials have natural enemies seeking to return them in longer or shorter time to proverbial dust. To some the enemy is water, to others air, or sun, or molds, or erosion. Used within its limitations, and properly detailed, wood has a permanence far exceeding most architectural requirements.

Among other factors having structural effects is the ease with which curved shapes of high structural efficiency may be formed. This has important competitive advantages over a purely structural plane over materials not so readily formed. Lengths and sections of glued laminated timbers are limited only by shipping facilities, making possible continuous members of great size and many shapes, never before available in timber. These members are dimensionally stable, thus being compatible with related constructions and free of the necessity of connector maintenance.

Economic Gains

In the realm of cost, wood has long been a construction material of proven economy. A plentiful and renewable natural resource in this country, it is readily workable and highly versatile.

In general, the added values built into it by laminating more than compensate for the added costs. The improved charactertistics obtained have multiplied the versatility of the material, making it useful for new functions. Obvious examples of this are recognized in curved shapes and members of large size. Many others can be cited where dimensional stability or improved appearance are properties essential to new functions. Other factors attending the growth and progress of the lumber industry, such as the high rate of demand for plywood, have contributed to the need for laminating as a means of up-grading the supply of lumber economically available.

Laminated sections permit skeleton or "post and timber" construction, eliminating load bearing walls, and precision shop fabrication effects substantial field savings in layout and erection.

The question is often asked whether laminated structural framing is low

i cost than other structural systems. ere is, of course, no simple answer such a question as various structural terials do not produce exactly com- able results. It is necessary first to line all of the design requirements cting planning, structure, appear- fire-resistance, maintenance, ting, and location. In some in- ces, where structure alone is im- ant, laminated framing has a ided cost advantage. This is most nounced in relatively long spans, n efficient structural shapes are readily formed in timber. In ot rs, however, the advantage might lie with competitive materials. The ess ntial economic advantage of lami- nated material rests principally upon its combined structural and appearance characteristics.

"TRUTHFUL IN EXPRESSION OF NATURE AND FUNCTION"—Church in West St. Paul, Minn., by Tussler & Setter, architects.

Aesthetic Qualities

As appearance and beauty are the least understood and most saleable asset of laminated timbers, no review of its architectural characteristics can be adequate without attention to this complex quality. Many are the definitions of beauty in our literature, and just as many are its meanings. For beauty is a personal quality as variable in its nature as the individual. Like most of our cultural and human values, it cannot be adequately evaluated in the laboratory and defies the scientific method.

Nevertheless, the architect strives, perhaps even presumes, to incorporate some of this magic ingredient in his designs. Frequently, he is successful beyond belief, thus acquiring the aura of mystery of a modern witch-doctor.

In this serach for beauty, it has often seemed to me a manifestly reasonable starting point to begin with a material which has a widely recognized natural beauty. This tends to simplify the problem and may be the reason that architects enjoy working with timber. However, it is only fair to reflect that many designers have attained striking beauty with the most unlikely materials.

The aesthetic and intellectual qualities contributing to the beauty and character of a building are, in fact, very largely a design result. Any architectural material is, in this sense, a medium of artistic expression rather than an art form in itself, and laminated material is a versatile tool of the designer. Its plastic qualities and workability lend themselves to balanced and graceful forms of great interest. These forms are often employed as dominant interior architectural motifs, frankly expressing the structural plan. As dominants in the composition, they contribute to unity of the design, and normally are the basis for rhythmic bay arrangements.

Laminated structures, unlike concealed forms in other materials, are truthful in the expression of their nature and their function. They may be allowed to display their own individual character, associations, and emotional appeal. Wood, as a natural and familiar material, is rich in these qualities.

While the infinitely varied patterns of grain and color in wood have their own natural appeal, laminated wood adds a regular man-made pattern of laminating, a logical and precise expression of the material's nature. Texture, tone, and color may be varied by the many wood finishes available.

AMINATED SECTIONS PERMIT SKELETON CONSTRUCTION"— rary in Birmingham, Alabama. Van Keuren, Davis & Co., Architects.

"RICH IN CHARACTER AND EMOTIONAL APPEAL"—Residence in Tallahassee Fla. Prentiss Huddleston & Associates, architects.

FACTORS FOR EFFICIENCY IN

Lumber End and Edge-Gluing Operations

Fig. 1.—Lumber raw material stored in temperature conditioning area prior to processing.

Fig. 2.—Production ripping machines for ripping the lumber to width prior to removing the defects.

JOHN H. SYME

Development Director, Engineering and Development Division, Edward Hines Lumber Co., Hood River, Oregon

End- and edge-gluing is an economic way to convert low-grade lumber into high-grade products. Highlighted here are the factors that result in an efficient operation—from the preparation of the raw material to the trimmed and sanded lumber panel.

A CONTINUED INCREASE IN the cost of the forest raw material and a gradual decrease in its quality, coupled with the increasing demand for tailor-made products by the customer, has, within the last 10 years, made the end- and edge-gluing of lumber an economical method of converting lumber into a variety of wood products.

These economic trends have stimulated the development of process equipment which is capable of gluing lumber at a comparatively high production rate. The development of this type of equipment is being carried on zealously, and great strides will be made in the lumber-gluing field in the next few years.

In harvesting the forest raw material, the industry has naturally processed the higher grade raw material first. This was an economic necessity. Generally, the forests of today are producing a lower grade of wood material; today's lumber production contains a greater percentage of short lengths, narrow widths, and lower grades.

Lumber is customarily purchased in random lengths and in an assortment of widths. Specified length and specified width lumber may be available at a higher price, but more often than not, it is not available at all, particularly in large volumes. It is practically impossible, for example to purchase car-load quantities of 1- by 12-inch "C" and Better lumber in 16-foot lengths, at any price. Although the consumer may desire to purchase only this width and length, he is practically forced to accept a certain percentage of the shorter lengths and the narrower widths along with the material he desires. The same is true regarding a fractional width or fractional length. The consumer must buy the next larger size and cut this material back to the size which he requires, thus absorbing some waste in the process, plus the added cost of reworking the stock.

Through the process of lumber end- and edge-gluing, wood products can be manufactured to more nearly meet the customer's needs. Lumber can be supplied in quantity, in specified lengths and widths, to the fraction of an inch. In other words, the product can be tailor-made to the customer's requirements.

We are no longer limited in size and grade totally by the characteristics of the raw material. The width and length of the finished glued products, and to a great extent the thickness, are no longer limited by the raw material, but are primarily limited by the gluing equipment which we employ.

Preparing the Raw Material

The proper preparation of the raw material for gluing is as important as the gluing operation itself. The best gluing equipment in the world cannot compensate for poorly prepared raw material. Preparation factors which are of greatest importance include (1) kiln-drying and temperature conditioning; (2) pre-surfacing or blanking; and (3) ripping and trimming for removal of the defects.

Drying and Conditioning: For best results, the raw material must be kiln-dried to a uniform moisture content and be free of excessive crook, twist, bow, and warp. Generally speaking, where electronic curing equipment is employed, a moisture content range of from 6 to 10 percent is acceptable. If the moisture content of the raw material is not uniformly within the desired range, it is wise to install a continuous moisture detection device, which will segregate the unacceptable stock from the material which is not within the desired moisture content range.

It is also sometimes advisable, depending upon the storage conditions, to condition the raw material to a uniform temperature. Gluing difficul-

[1] Presented at the joint FPRS AIChE, and ASME Wood Industries Conference September 10, 1959 in Portland, Oregon.

Fig. 3.—Finger-joint scarfer feeding unit.

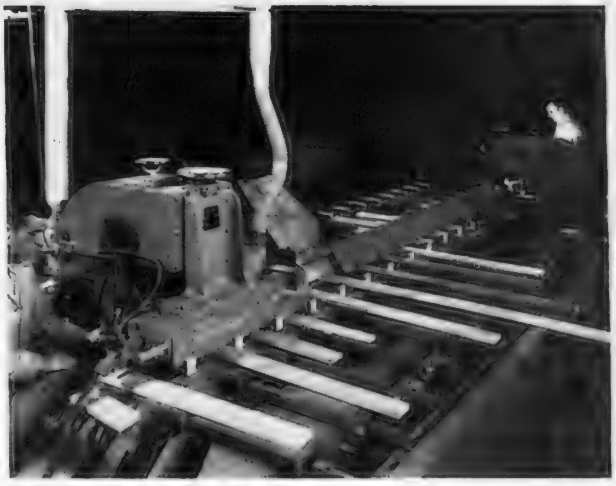


Fig. 4.—Finger-joint scarfers and transfer mechanism.

will be encountered if the temperature of the raw material varies over a wide range. This is particularly true where severe winter temperatures are encountered. For example, stock which is stored in an open shed at a temperature of –10°F. should be brought into a heated building and conditioned to room temperature prior to processing. Under these conditions, it is wise to provide a temperature-conditioning storage area, so that a large volume of stock can be stored and conditioned prior to gluing (Figure 1). Satisfactory stock temperatures are generally from 65° to 80° F.

Pre-Surfacing: Following kiln-drying, the stock should be surfaced to a fairly uniform thickness, either on one or on both faces. This is usually done on a high-speed planer or similar type of surfacing equipment. As an example, nominal 1-inch thick, rough lumber is normally surfaced, hit and miss, to a thickness of 27/32-inch or 7/8-inch. Stock which does not clean up should be re-run to a thinner thickness. Pre-surfacing, or "blanking", as it is usually referred to in the trade, enables the defects to be cut from the material effectively. Pre-surfacing also facilitates sorting out the thin material before it gets into the gluing process, and greatly increases the overall efficiency of both the end-gluing and edge-gluing processes. A uniform thickness is necessary in order to machine an accurate finger-joint on the material to be end-glued.

Defect Removal: Normally, the end- and edge-gluing operation is preceded by some type of a defect removal system in which the stock is ripped and trimmed in order to reduce it to the proper size for further processing and to remove the undesirable characteristics, such as large knots and pitch pockets, so that the grade of finished product can be controlled. This stock preparation may be confined strictly to the removal of defects from the material, or it might be operated in conjunction with a millwork cutting operation.

The defect-removal operations should be designed to (1) rip the stock to the proper widths, accurately and at a high rate of production (Figure 2); and (2) remove the defects by some type of cross-trimming saw. Particular attention should be given to the cross-cutting operation. In instances where knots or similar characteristics are being removed, care must be taken not only to remove the knot, but the wood containing curly or crooked grain surrounding the knot must also be removed. Otherwise, it is not possible to machine an acceptable finger-joint on the end of the piece.

Regardless of the method of defect removal used, it is of prime importance that the stock be carefully and accurately prepared.

Selecting and Preparing the Adhesive

The selection of the proper adhesive and the correct preparation of this adhesive are fundamental factors in operating a successful gluing plant. In many cases, the selection of the adhesive is left to chance or to the adhesive salesman who happens to be calling on the plant. Adhesive preparation equipment is, more often than not, inadequate and poorly maintained. The storage facilities provided for the adhesive raw materials should be given consideration, especially in areas where extremes in temperature are encountered.

Adhesive Selection: There are several adhesives on the market which can be used in a lumber end- and edge-gluing operation with good success. The end use, or uses, of the products which are being manufactured should be the most important factor in making the adhesive selection. If a portion, or all, of the products are to be used in exterior applications, it is then necessary to use an exterior adhesive. A suitable adhesive of this type is the combination of 50 percent melamine resin-and 50 percent urea resin. This adhesive has the obvious advantage of inconspicuousness due to its colorless glueline, and it produces wood-to-wood bonds having high boil resistance and acceptable exterior durability. For products which are confined to interior application only, a straight urea-resin adhesive can be employed. This adhesive also has a colorless glueline, and it possesses adequate durability for most interior applications. There are other adhesives which are in common use for end- and edge-gluing, but the writer will not attempt to discuss them here.

The selection of the adhesive will dictate, to a certain extent, the type of equipment which will be used in the process. For example, the urea-resin adhesives can be cured either at room temperature or by radio frequency or other sources of heat. The melamine-urea combination requires elevated temperatures to cure the glueline. A radio-frequency generator is the most common method used for curing the melamine-urea glueline. Steam or electric heaters are sometimes used.

The cost of the adhesive is often an important factor, and it might be well to point out the approximate costs of the two adhesives. The mixed cost of the straight urea adhesive is about 16¢ a pound, and the mixed cost of the melamine-urea, 50–50 mix, is in the neighborhood of 23¢ per pound. These costs may vary slightly depending upon the quantity purchased and the exact formula used.

Fig. 5.—Assembled cut-to-length stock enroute to curing tunnel.

Adhesive Preparation: The adhesive must be properly prepared in order to do an effective job of bonding the wood. Storage facilities should be supplied with constant temperature control equipment; a temperature range of from 65° to 70°F. is satisfactory. The use of an accurate scale or balance is important if the glue is to be formulated properly. The adhesive ingredients must be measured accurately and uniformly for each mix. The glue-mixing machine is an important piece of equipment; the double action type is preferable and it should have adequate capacity for the volume of adhesive to be mixed. Other pieces of equipment should be provided which facilitate accurate mixing and ease of handling of the adhesive. All glue-room equipment should be thoroughly cleaned at regular intervals.

End-Gluing

Basically, the production end-gluing unit should consist of (1) two finger-joint scarfing machines, equipped with an automatic transfer between the two units; (2) an adhesive applicator; (3) an assembly machine; (4) a glueline curing unit; and (5) an automatic cut-off saw.

An end-gluing unit of this type should maintain a production of 10,000 board feet per 8-hour shift, based on 1- by 4-inch random-length stock; this board-foot production figure will naturally be increased when thicker and wider stock is processed. Most end-gluing units can be designed to process stock up to 2 inches in thickness, 12 inches in width, and from 10 inches to 8 feet in length.

Labor requirements for an end-gluing line of this type are quite variable; however, three workmen can normally operate and maintain a properly designed unit. One workman feeds the first finger-joint scarfer; the second man off-bears and grades the cut-to-length, end-glued lumber behind the glue-curing unit; the third workman is responsible for the overall operation of the unit which includes maintenance and changing of the cutterheads and saws, machine adjustments and repairs, and responsibility for the volume and quality of the material processed through the end-gluer.

Finger-Joint Feeder: Logically, the workman who feeds the first finger-joint scarfer largely determines the rate of production of the total end-gluing unit; thus, it is important to provide him with mechanical help so that he can feed the machine as efficiently as possible. Normally, on 4/4 stock, the machine is usually operating at a rate of 60 feed lugs past the cutterhead per minute. This means that the workman must pick up a piece of stock and place it in front of the lug every second in order to keep up with the machine. This is practically impossible without some sort of mechanical devices to assist him. The problem is made more complex by the fact that usually narrow width, random length stock is being fed into the machine. Typical stock going through the end-gluing unit might be 4 inches in width and could vary from 12 inches to 8 feet in length.

Normally the stock is palletized into loads as it is sorted from the defect-cutting line. The feeding equipment must then be designed to handle these pallet loads of random length stock. A simple but effective feeding unit might be utilized which would consist of a storage conveyor feeding into a tilt-lift arrangement. The pallets of random length stock would be placed on the storage conveyor, and they would be automatically brought into position and spilled onto a wide belt conveyor by the pallet lift. The stock from the wide belt conveyor then drops onto a narrower belt, feeding endwise to the workman, who would merely pick the stock off of this belt and place it in front of the lugs on the finger-joint scarfing machine (Figure 3).

Machining the Finger-Joint: In the production system, the finger-joint is machined by passing the piece of stock by a trim saw and a revolving cutterhead at a fairly high rate of speed. The trim saw accurately trims the end of the piece, and the cutterhead machines the finger-joint into the end of the piece. The finger-joint must be machined with as little tolerance as possible. This, of course, means the use of a balanced motor and cutterhead, tapered spindles, and other features which are generally accepted in accurate machining work. The other important factor in cutting an accurate joint is the holding or clamping of the wood as it is moved past the cutterhead. If the piece is allowed to move out of alignment only a few thousandths of an inch as it comes in contact with the cutterhead, a poorly machined joint will result. For this reason, the design of the hold-down assembly on the finger-joint scarfers is the key to cutting an accurate finger-joint.

The transfer unit following the first finger-joint scarfer transfers the stock automatically into position for the second scarfing unit. At the same time, it must maintain the position of the stock so that the finger-joint on the opposite end of the piece is machined with reference to the same edge which was used in cutting the first joint. This positioning is necessary because of the wedge-like shape of some of the pieces being finger-jointed. If the two edges of the piece are not parallel, and if one edge is used as a reference for machining the joint on one end and the other edge is the reference for machining the finger-joint on the opposite end, the two joints will not be machined parallel to each other; and therefore, cannot be assembled tightly and in a straight line.

The second finger-joint scarfer is identical to the first, except it is of the opposite side; each of the scarfing units machines a finger-joint on opposite ends of the lumber pieces being processed.

Figure 4 shows two finger-joint scarfing units and transfer system.

Adhesive Application: The adhesive can be applied to both ends of the finger-jointed piece, or it can be applied to only one end; this is usually determined by the species being processed and the amount of adhesive applied to the finger-joint. In Douglas-fir and pine operations, it is customary to apply glue to one end of the piece; while it is applied to both ends in most redwood and cedar plants. For best results, however, it is recommended that the adhesive be applied to both ends of the piece, regardless of the species being processed.

Two types of glue applicators are conventionally used—the disc applicator and the pressure pump. The disc applicator utilizes a revolving disc machined to the configuration of the finger-joint; it revolves in a manner to wipe glue on the finger-joint as it is passed by the disc. The second type of applicator is of the pressure type

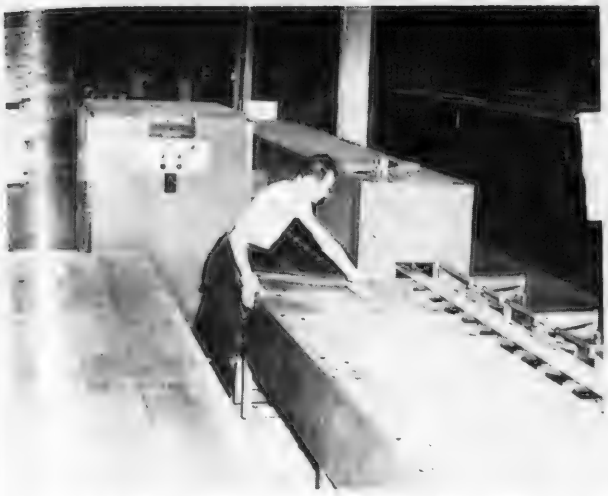


Fig. 6.—High-frequency tunnel for curing finger-joints.

Fig. 7.—Dual edge-jointing machine with movable cutterhead.

with a head also machined to the configuration of the finger-joint and containing small orifices which are connected to an air pump and thence to the glue pot. As the finger-jointed piece passes the pressure head, it triggers a limit switch which actuates the pressure pump, thus forcing glue through the openings in the pressure head, which is wiped on the joint. Both methods of application have seen considerable use, but neither one is entirely satisfactory. Control of the amount of adhesive applied is difficult with the disc applicator, which results in high glue waste. The pressure pump applicator is subject to considerable clogging at the orifices; adhesive spread is also difficult to control satisfactorily. There is need for the development of an efficient glue applicator for applying the adhesive to the finger-jointed stock.

It is suggested that the adhesive storage vessels be equipped with water jackets to enable the adhesive to be maintained at a constant temperature. This controls the glue viscosity, which is an important factor in maintaining a uniform rate of spread.

Joint Assembly: Following the machining of the finger-joint on both ends of the piece and the subsequent application of glue, the next step is to assemble these random length pieces into a continuous ribbon of length. This is done on an assembly machine, employing a friction feed which drives or meshes the finger-jointed stock together. This can be accomplished by a belt assembly-feed against a clamping device, or a belt assembly or roll assembly in which the second roll or set of belts operates at a lower speed than the first set, thus acting as a crowding mechanism. Two basic types of assembly machines are in use today. The first one assembles the stock into a continuous ribbon through the use of the differential speed rolls, cuts it to the desired length, and moves it into another section of the assembly machine which applies end-pressure to the cut-to-length piece in order to force the joints together tightly. The second type of assembly unit uses more force in the crowding mechanism, and apparently meshes the joints tightly during the initial assembly. The assembled piece is then cut to length. Production rates on the assembly machines will vary from 60 to 100 lineal feet per minute, depending upon the stock being processed. It is not uncommon for a production-type assembly machine to operate at 90 to 100 lineal feet per minute on 1- by 4-inch stock, for example.

The most important single factor in the design of an assembly machine is that it must assemble the joint tightly. This is especially true where the finger-jointed lengths will be subsequently used for millwork items and lineal moldings in which a contour pattern is machined in the piece which cuts through the finger-joint and, of course, will expose any portion of the joint which is not assembled with a complete tight fit. The quality of the finished product is determined largely by the tightness of fit of the finger-joint.

Curing the Glueline: Following the assembly of the finger-jointed stock, the glueline should be cured by one method or another. In many cases, the finger-jointed lengths are merely stacked, and the glueline is allowed to cure at room temperature. Other equipment is available which heats the lineal stock by use of steam, infra-red units, or electrical strip heaters, thus curing the glueline. Generally, these types of curing do not employ any end or surface pressure.

High-frequency electronic generators coupled to an electrode system, are being used extensively to cure the glueline in finger-jointed products (Figure 5). During the past two years these units have been developed to a point where their operation is quite satisfactory. The curing units are placed directly behind the assembly machine and are capable of curing the stock at the maximum rate of production of the assembly unit. The finger-jointed stock is either cut to length prior to entering the curing section or following the curing cycle, depending upon the type of assembly machine being used.

The high-frequency generator is usually designed to produce a power output of approximately 20 kilowatts at a frequency of about 10 megacycles. The generator circuit should possess the required stability to maintain the peak power output for which it is tuned, dependent upon the width and thickness of the lumber stock being processed.

The electrode system is comprised of two parallel metal electrodes approximately 20 feet in length. The finger-jointed stock is passed between the two electrodes in a lengthwise direction with the electrodes being located along the edges of the stock. Thus, the electronic units are sometimes referred to as "curing tunnels". The electrodes are adjustable for the various widths of stock processed.

The necessity for maintaining end and face pressure on the finger-jointed stock being cured in the electronic unit is still a subject of considerable controversy. Research is presently being carried out to provide more information on these and other important aspects of curing the finger-joint glueline.

Fig. 8.—Application of glue to jointed strips; electronic curing press.

Edge-Gluing

The edge-gluing unit processes narrow stock of a pre-determined length into the desired greater widths by gluing the pieces together edge to edge. The edge-gluing unit consists of (1) an edge-jointer, which prepares both edges of the incoming raw material for gluing, (2) a pre-layup section where the proper width of panel is composed, (3) the glue applicator, (4) the curing press, (5) trim saws for cutting the panel to length, (6) a surfacer such as a sander or side planer, and (7) a ripping machine for ripping the proper widths from the wider edge-glued panel. The above operations or steps can be separated into two groups—(1) the edge-jointing, pre-layup, glue application, curing, and panel trimming; and (2) panel surfacing and ripping.

The first portion of the edge-gluing unit is capable of a production of 15,000 to 20,000 board feet per 8-hour shift, depending upon the type of material being edge-glued. Two workmen, an edge-jointer feeder and a press operator, can normally operate this portion of the edge-gluing unit.

The second section of the edge-gluing unit, panel surfacing and ripping, is capable of processing about 30,000 to 40,000 board feet per 8-hour shift. A well designed line of this type can be operated by one workman.

Edge-Jointer: The preparation of the edges of the stock to be edge-glued is the most important single step in the edge-gluing operation. It is impossible to do a satisfactory job of edge-gluing unless the edges of the incoming lumber are jointed smoothly and squarely.

Several methods of edge-jointing are in general use today, and these fall into two categories—(1) those in which a saw is employed to prepare the edge-surface, and (2) those applications where the edge-surfacing is done with a cutterhead. Either method is satisfactory provided that the machine is properly designed. Until recently, the common practice has been the use of two single saws, or cutterheads, placed in series. The first machine joints one edge of the stock, and the second machine joints the opposite edge. This is an expensive operation due to the requirements for two machines and operators.

Dual machines have been recently developed which eliminate many of the disadvantages of the equipment used in the past. These machines can be obtained in either the saw or the cutter-head type. Basically, the machines consist of one fixed saw or cutter-head and one moveable saw or cutter-head; the adjustment of the moveable side is accomplished through an electrical control panel actuating a hydraulic mechanism. Since these dual machines joint both edges of the lumber at the same time, the width of the jointed piece remains constant from end to end and can be held to a very close tolerance. Random width stock can be processed efficiently on the dual machine due to the quick adjustment of the moveable side. A well-designed dual edge-jointed is capable of maintaining feed rates up to 250 lineal feet per minute.

The design of the holddown portion of the edge-jointer should receive consideration, as should the method of conveying the stock through the machine. A chain-feed or traveling-feed bed is a necessity so that the stock can be carried through the machine in a straight line. The holddown units apply pressure to the top of the piece, so that it will not slip on the feed chain. They are usually comprised of a series of rubber-faced wheel units mounted on either side of the cutterhead or saw section. The feed mechanism and the holddown units must be properly designed so that the piece will be held firmly and the edges will be jointed straightly and squarely (Figure 7).

Pre-Layup Section: Following the edge-jointing operation and prior to the application of the adhesive to the edges of the stock to be edge-glued, the jointed strips should be assembled into the proper panel widths. In many cases, narrow filler strips of various widths will be required, particularly when random-width stock is being processed. This pre-layup operation is necessary due to the limited side-stroke of the edge-gluing press. Normally, the edge-gluing press has a side-stroke of approximately 3 to 4 inches. If the press is adjusted for a 48-inch minimum width, for example, then the range of the pre-layed widths transferred to the press should be between 48 and 51 inches. If the pre-layed panel is wider than this, it will not go into the press; and if it is narrower than 48 inches, the press will be unable to exert the proper side pressure on the assembly, and a poorly glued panel will result.

The pre-layup operation can either be accomplished as a separate handling operation following jointing of the edges, or it can be mechanically accomplished as the stock is being transferred between the edge-jointed and the glue applicator. The latter method is the most economical, but requires considerably more equipment.

Adhesive Application: Application of the adhesive to the edges of the stock to be edge-glued is a relatively simple matter. This can be done in a number of ways. Primarily, the adhesive can be successfully applied by the use of either (1) a grooved metal roll, or (2) a pressure wiping mechanism. Where the grooved applicator roll is used, the roll is usually mounted in the glue pot, and it picks up adhesive out of the container—the amount being picked up is determined by an adjustable doctor blade. The stock is then propelled lengthwise in contact with and past the roll which applies glue to the edge of the piece. In the case of the second method, the piece is moved past a serrated orifice which opens as the stock contacts it, and the adhesive is forced through the orifice and is wiped on the edge of the board. Regardless of which method is used, it is of extreme importance that the stock be held firmly against the glue-application tool throughout the length of the piece so that the glue is applied to the full length of the stock. Normally, adhesive is applied to only one edge of the piece.

Both of these methods are adaptable to high-speed application, and it is not uncommon for these units to be operating with stock moving at 200 or more lineal feet per minute.

Curing the Glue: Immediately following the application of the adhesives, the pieces are assembled edge-to-edge in preparation for the gluing curing cycle which is accomplished in a curing press (Figure 8). Both steam presses and electronic units are used for edge-gluing. The electronic type is much more in demand due to its fast cycle and the fact that it does not reduce the moisture content of the

stock being processed. The edge-gluing press is usually a single-opening machine, capable of applying both face pressure and side pressure. The newer units are completely automatic. The stock is moved into the proper position and face and edge pressures are applied with the momentary release of the face pressure which allows the edge or side pressure to equalize throughout the panel. At the end of the pre-determined cycle, the press opens, and the stock is again moved forward the required amount. A press such as is being described is commonly known as a "stop-and-go" or "batch" press. Usually the platen is 8 feet in length; therefore the panel to be edge-glued is moved forward in 8-foot increments. The incoming panels are butted end-to-end so that the press operates on a continuous ribbon of stock.

An electronic press with a 4- by 8-foot platen will generally be equipped with a 30 to 40 KW high frequency generator. This allows the maximum energy to be transferred to the glueline, thus curing the glueline as rapidly as possible. As an example, on 4/4 stock made up of narrow, 3-inch widths, a 4-foot wide by 8-foot long section can be cured in approximately 30 seconds. To this curing time, an additional 10 to 15 seconds must be added for moving the panel forward and closing and opening the press.

Fig. 9.—Overall view of panel sanding and ripping line.

Trimming, Ripping, and Surfacing: The sizing of the edge-glued panel to the proper dimensions is accomplished by trimming, surfacing, and ripping. Although these operations can be done in practically any sequence, and with a variety of equipment, it is necessary to consider several factors in order to develop the proper procedure. First of all, it is assumed that the edge-glued panel has been made up into the proper rough width from which will be cut several smaller components with the minimum amount of waste. For example, if the end product is to be in 12-inch widths, then the edge-glued panel would be made up in approximately a 49-inch width; which would allow the 12-inch pieces to be ripped from the panel with little waste.

One method of accomplishing the length-sizing operations is the placement of the panel trim-saw directly behind the edge-gluing press. The panel trimmer should be capable of trimming the ends squarely and to extremely accurate lengths. It is usually desirable for the trimmer to be equipped with several adjustable saw units, so that a multiple of lengths can be cut from a long panel in one pass through the machine. If an automatic stacker is provided behind the panel-trim saw, then this operation can be accomplished without the use of a saw operator. Following the trimming operation, it is usually recommended that the panels be stored for several hours so that the glue squeezeout on the surface of the panels is allowed to harden and to condition the panels to prevent sunken joints before the surfacing operation is undertaken.

The surfacing of the wide edge-glued panels can best be done on a heavy duty, multiple-drum sander. An eight-drum, double-deck machine is suitable for this purpose, and probably the newly developed wide-belt sanders, or combination drum and wide-belt sanders, would do a satisfactory job on this application. Wide planing machines normally are not capable of maintaining the desired thickness accuracy and smoothness at the desired rate of feed. The type and grit of paper used on the sander is determined by the raw material being processed and the desired characteristics of the finished product.

The ripping of the edge-glued panel to the proper widths can usually be done in conjunction with the surfacing operation. Following surfacing, the stock can be moved directly into the ripping machine. The ripping machine must be capable of ripping the stock accurately and in a straight line and must also produce a finished edge as the ripping is accomplished. A modified double-end tenoner is an excellent machine for this purpose; this machine can also be used for other specialty work such as tongue-and-grooving, ship-lapping, and other edge and surface work.

Conclusions

The wide-spread use of lumber end- and edge-gluing facilities has has only been apparent in the past 2 or 3 years. As these operations become more and more prevalent, the industry will see a rapid development in equipment and methods by which end- and edge-gluing can be accomplished.

The forest products industry is attempting now, more than ever before, to convert its raw material into products which more nearly meet the needs of the consumer. Lumber end- and edge-gluing is an important step in this direction. Through this process, we are no longer limited by the length and diameter of the log. We can produce lengths of lumber materials and related wood products which are desired and needed by the consumer regardless of the character of the incoming raw material. We can build up widths of lumber products which are far in excess of anything that the tree could produce in one-piece material.

We are on the threshold of a new era in lumber manufacturing. At the same time, we face stiffer competition from other materials which are invading our markets. Lumber end- and edge-gluing will help us maintain, and perhaps strengthen, our standing in relation to these other competition materials.

Solvent Seasoning of Tanoak[1]

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Tanoak sapwood was dried to 10 percent moisture content in less than 30 hours—in contrast to the months required by other seasoning methods—and the lumber was relatively free of seasoning defects.

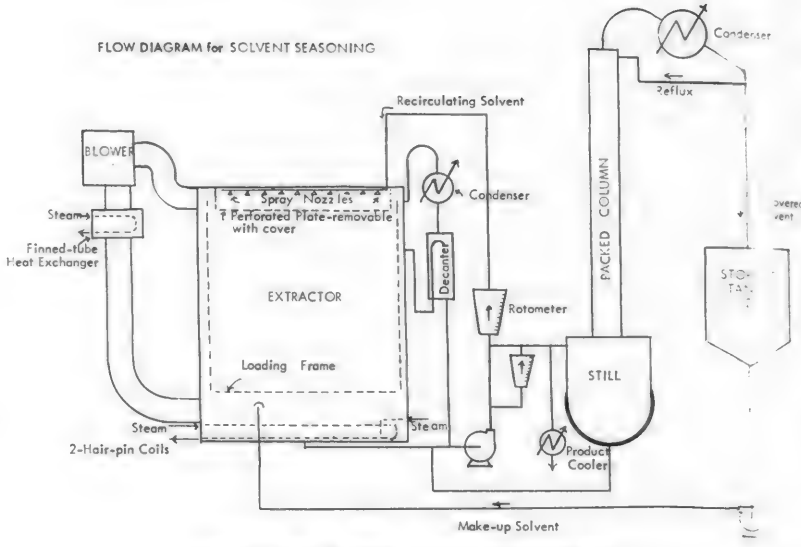

Fig. 1.—Flow diagram for solvent seasoning unit.

TANOAK *(Lithocarpus densiflorus* Rehd.)[3] is a major hardwood species in California, totaling a little over two billion board feet with minimum sawlog diameter of 11 inch (1)[3] This species is largely confined to the coastal region in association with redwood and Douglas fir extending from Southwestern Oregon to Southern California. Tanoak, which is not a true oak, may reach a height of 200 feet and may have a diameter of up to 3 feet or more (2).

Tanoak assumed importance a little over a century ago not as a source of lumber, but rather for its bark which was prized and used extensively for tanning leather (3). During the last half of the past century, approximately 15,000 cords of bark were harvested annually. Until recently, the annual bark production was about 8,000 cords, from some 6 million board feet of timber (4). The general practice over the years has been to strip the bark from the felled trees and leave the debarked log in the forest to decay (3). Early attempts to recover lumber from tanoak logs indicated that this species was not amenable to conventional methods of seasoning. Even if allowed to air dry, which is perhaps the mildest of drying conditions, it would invariably stain, check, and warp. The early experience discouraged operators from salvaging the logs for lumber production.

In recent years, expanding forest products research facilities and increasing interest in extending the recovery of lumber resources resulted in new efforts to recover lumber from tanoak (5, 6). The conclusion drawn was that the highest recovery of tanoak lumber would result if the lumber was first allowed to air dry to a moisture content of approximately 20 percent followed by kiln drying (7, 8, 9). Direct kiln drying from the green caused excessive seasoning defects such as collapse, checking, cupping, and warping. Even the recommended procedure left much to be desired in the way of reasonable recovery of usable tanoak lumber.

The Authors: Arthur Anderson holds a Ph.D. from the University of Wisconsin, and he is now chief of the forest products chemistry division at the California Lab; Watson Fearing is section leader in the chemical processing section. He earned a B.S. in chemistry and a B.S. in chemical engineering at the Univ. of Calif.

The Solvent Seasoning Process

It appeared that other methods of drying merited investigation in attempting to season refractory hardwoods such as tanoak. One of the special seasoning methods, among the arsenal of unused wood drying process, was developed some 17 years ago by the Western Pine Association and is known as solvent seasoning (10, 11, 12, 13, 14). This process uses water miscible organic solvents to remove water from green lumber. Basically, green lumber is stacked vertically in a vapor-tight extraction chamber and a heated water miscible solvent, such as acetone, is circulated by means of a pump over the lumber at atmospheric pressure. As the hot solvent passes over the lumber, it extracts or removes the water in liquid form. When sufficient water has been extracted from the lumber, the retained solvent, which largely replaced the water, is removed by circulating hot air or inert gases followed by a short steaming period. Since the solvent, i.e., acetone, has a much higher vapor pressure than water, the solvent removal and recovery period usually takes only from 4 to 8 hours. All solvent recovered is reused. When the effluent solvent is stripped, or distilled from the water, the latter will also contain any extractive components removed from the lumber during the solvent circulation, or extraction period. The type of extract recovered as a by-product will, of course, be contingent on the species being seasoned. In the case of ponderosa pine, for instance, approximately 60 pounds of extractives were recovered per 1,000 board feet of lumber processed. This extract consisted of fatty acids, resin acids, and neutrals somewhat comparable to the composition of tall oil. A volatile fraction of terpenes was likewise recovered as a by-product (11).

[1] Presented at Session VIII, Wood Drying, FPRS 13th National Meeting in San Francisco June 30, 1959.

[2] Numbers in parentheses refer to Literature Cited at the end of this report.

[3] Authors acknowledge partial sponsorship of California Division of Forestry and laboratory assistance of J. Boyden, A. Rezai, and J. Batchelder. Union Lumber Co. supplied the tanoak; Oronite Chemical Co. the acetone.

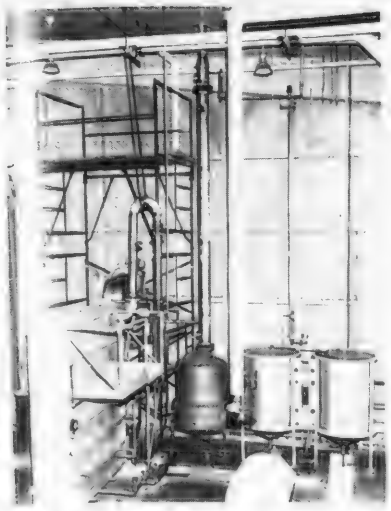

Fig. 2.—Solvent seasoning unit during installation: extraction chamber, left; distallation unit and column, center; and solvent storage tanks, right.

Laboratory Procedure

The stainless steel solvent seasoning pilot unit used in this investigation has a capacity of 200 board feet and will handle boards up to a maximum length of 6 feet (Figs. 1 and 2). Stainless steel was specified to avoid any corrosion problems that might arise due to the acidic or corrosive nature of extractives which might be encountered when processing certain woods.

Most of the tanoak used in this investigation came from the Ft. Bragg, California area. The diameters of the logs used in this study varied from 17 to 30 inches and contained, on the average, about 81 percent sapwood. Each shipment consisted of approximately 200 board feet of freshly cut 4/4 green random width stock sufficient for about three runs. As soon as the shipment was received, the material was placed in cold storage to keep the stock as green as possible prior to seasoning. Since preliminary runs indicated that the drying rate for tanoak heartwood was much slower than for sapwood, segregation of the stock before seasoning was immediately indicated. In this report, all runs were confined to 4/4 tanoak sapwood.

The general procedure used in carrying out the various solvent seasoning runs was as follows:

Twelve boards were selected, and samples were taken for moisture content. The boards were then cut into 6 foot length. A 1/4-inch hole was placed about 6 inches from each end of the boards, and each board was weighed to obtain the total green weight. An aluminum bolt was next passed through the holes at each end of the six boards and a 1/4-inch thick aluminum washer added between each board. These washers acted as spacers, or stickers, to separate one board from another to permit exposure of all surfaces to the solvent during the extraction cycle. Each of the two six-board packaged units was put in a framed rack in vertical position. The loaded rack, containing from 40 to 60 board feet of lumber, was lowered into the extractor, and the lid of the extractor was secured. Sixty gallons of acetone were pumped into the bottom of the extractor and solvent heated to near its boiling point (130° F.) by means of immersed heating coils located at the base of the extractor. The heated solvent was circulated by means of a centrifugal pump through a flowmeter and then through spray nozzles located in the top of the extractor, permitting the solvent to flow over each board. While the solvent was being circulated, the rate of water removal from the green stock was obtained by determining the specific gravity of the circulating solvent at various intervals. After every hour, a quantity of solvent, usually 5 to 20 gallons of known water content, was pumped as effluent to the still, after which a like quantity of fresh solvent was added to the extractor. By recording the amount of water removed, the average moisture content of the lumber charge at any time was readily determined. When the moisture content of the boards reached about 10 percent, the circulation was stopped and the extractor drained of solvent.

The next step was to remove the solvent picked up by the boards during the extraction cycle. The solvent-removal cycle was carried out by applying heat by means of a unit heater and blower, placed in the external duct which was connected to the base and top of the extractor to aid in heat transfer by rapid circulation of the vapors. The solvent vapor so removed was condensed and recovered. When most of the solvent had been removed, saturated steam was blown into the extraction chamber to accelerate removal of residual acetone and displace the solvent vapors remaining in the system. After the solvent-removal cycle was completed, the boards were removed from the extractor, weighed, and moisture content was determined.

Effect of Board Position

Several preliminary solvent seasoning runs were made to ascertain the effect of board position in the extractor on rate of water removal. For this purpose, the first run was made using the preferred method—putting the boards in vertical position and spraying the solvent over the boards. In the second run, the boards were also in upright position, but they were immersed in solvent. In the third run, the boards were placed in horizontal position and immersed in solvent. The drying rates to 10 percent moisture content in each of these runs are summarized in Table 1.

Table 1.—EFFECT OF BOARD POSITION ON EXTRACTION RATE (4/4 TANOAK)

Run no.	Board position and condition	Time to 10 percent M. C. (hrs.)
1	Vertical, solvent sprayed	24
2	Vertical, immersed in solvent	55
3	Horizontal, immersed in solvent	160

It becomes immediately apparent that board position plays a major role in the rate of drying. The vertical, solvent-sprayed method required 24 hours. Boards in the same position but immersed in solvent took more than twice as long, and the immersed boards in horizontal position took more than six times as long as those in the preferred position. These results clearly showed that in placing the boards on end and allowing the solvent to flow onto the boards, the solvent entered the vessels and other cell openings. As the solvent moved downward by gravity flow, it extracted the water and any soluble extract present throughout the thickness and length of the board. This was manifest since the boards were completely satu-

Table 2.—EFFECT OF SOLVENT TEMPERATURE ON EXTRACTION RATE (4/4 TANOAK)

Solvent temperature	Time to 10 percent M. C. hrs.)
100°F.	66
115°F.	52
130°F.	22

Table 3. -- SOLVENT SEASONING RUNS ON 4/4 TANOAK

Run No.	Green M.C. dry basis per cent	Acetone concentrations during extraction cycle per cent by weight		Per cent acetone concentration greater than equilibrium maintained during extraction cycle	Extraction cycle Hours		Solvent recovery cycle Hours		Total time Hours	Final Av. M.C. dry basis per cent
		Initial	End		to 10% M.C.	Total	Heating	Steaming		
13	80-92	99.7	99.4	< 100	24	33	4-1/6	1/3	37-1/2	7.2
14	74-96	99.7	99.4	< 100	24	28	6-1/3	1/3	34-2/3	8.7
25	87-107	99.7	98.8	< 100	25	26	7	1/2	33-1/2	8.3
27	84-99	99.7	98.8	< 100	25	29	7	1	37	11.2
33	105-118	73.0	97.6	69	21	28	5-3/4	1/2	34-1/4	7.7
34	107-120	53.0	96.9	48	33	37	7-1/2	0	44-1/2	9.5
35	100-111	73.0	97.6	69	21	23-1/3	6-1/3	0	29-2/3	11.6
37	85-104	62.0	97.5	58	21	26	6	1/2	32-1/2	7.4
38	84-100	59.0	97.7	54	27	30-1/2	7-2/3	1/2	38-2/3	8.7

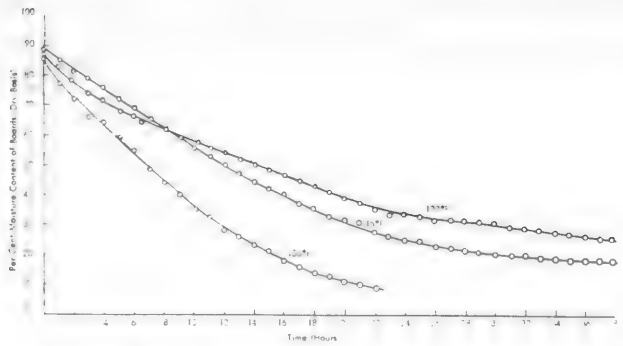

Fig. 3.—Effect of solvent temperature on water removal.

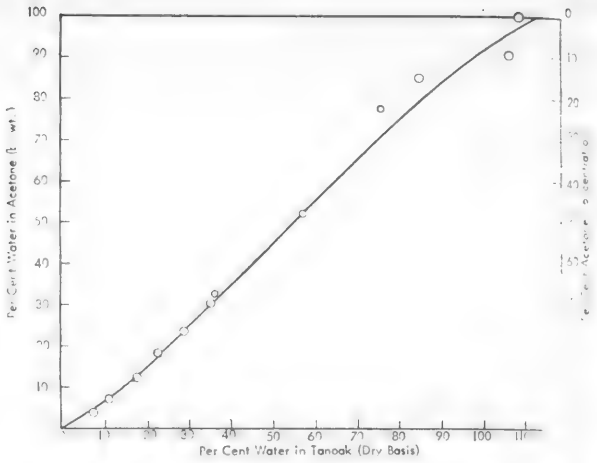

Fig. 4.—Equilibrium curve for Tanoak sapwood at 135° F.

rated with the solvent at the close of the extraction cycle. These results corroborated the findings on solvent drying rates for ponderosa pine sapwood. All subsequent runs were carried out using the vertical position, solvent-sprayed method.

Effect of Circulation Rate and Temperature

Among the variables to be determined was the quantity of solvent to be recirculated to maintain optimum drying rates. After a series of runs, it was found that above 100 gallons per minute per 1,000 board feet based on 6 foot board lengths, or about 40 gallons per minute per 1,000 board feet for 16 foot boards, did not seem to affect the drying schedule.

Another variable to be established was the effect of temperature of recirculating solvent on drying rates. A series of three runs was made using solvent temperatures of 100° F., 115° F., and 130° F. The results are summarized in Table 2.

It is apparent that considerable reduction in drying schedule can be realized if the solvent temperature is kept as high as possible during the extraction cycle. The rate of water removal at these various solvent temperatures is shown in Fig. 3.

Effect of Solvent Concentration

One of the important factors to be determined was the purity of solvent necessary during the extraction cycle to maintain optimum, or near optimum, drying rate. For this purpose, it was desirable to determine the points of equilibrium between wood at various moisture contents and water content of the solvent. The equilibriums were determined on ¼ inch wide strips cut from a fresh green 2-inch by 5-inch cross section of tanoak sapwood of known moisture content. Several of the weighted strips were transferred to a quart Mason jar, immersed in acetone of known water content after which the jar was sealed. The jars were put in a constant temperature bath at 135° F. (the boiling point of acetone) and held until the specific gravity of the solvent remained constant. The jar was then removed, cooled to room temperature, the solvent decanted and weighed, and the moisture content determined by specific gravity after correcting for extract content. Knowing the moisture content of the solvent after each equilibrium determination, the amount of moisture remaining in the wood was readily calculated. The equilibrium data are plotted in Fig. 4.

These data indicate, among other things, that in order to arrive at 10 percent moisture content for 4/4 tanoak sapwood at the close of the extraction cycle, the solvent must not be less than 94 percent acetone. It is apparent in actual operation that the solvent concentration should actually be somewhat higher since to continue the extraction cycle until actual equilibrium is reached would be too time consuming. In any event, dry acetone would not be required at the close of the extraction cycle to bring the stock to the desired moisture content, i.e., 8 to 10 percent.

The equilibrium data also show that at the start of the extraction cycle the acetone used could be quite dilute and still remove water from green stock. Therefore, it was of interest to start extraction cycles with various concentrations of acetone which were greater than equilibrium. For a typical run, for instance, a point was chosen below the equilibrium curve with lumber at 100 percent moisture content. As an example, a point 69 percent below the equilibrium point at 100 percent moisture content would place the acetone concentration at 73 percent (Fig. 5). The 69 percent equilibrium points at various wood moisture contents were similarly determined and plotted. With this information, a run could be made in which the acetone concentration could be maintained at a 69 percent level ahead of the equilibrium curve throughout the extraction cycle. For want of a convenient term, this percentage acetone concentration ahead of equilibrium has been designated as "driving force" of the solvent. In addition to runs being made at various driving force levels, runs were made in which the acetone concentration during the extraction cycle was maintained at highest purity possible, or at a driving force of slightly less than 100 percent. The results of some of these solvent seasoning runs are summarized in Table 3.

When the driving force of the solvent during the extraction cycle was maintained at around 100 percent (Runs 13, 14, 25, and 27), it required about 24 to 25 hours to bring the moisture content of the lumber to 10 percent. Interestingly enough, when the driving force of the solvent was kept at 69 percent (Runs 33 and 35) and 58 percent (Run 37) levels, the extraction cycle to 10 percent moisture content was reduced to 21 hours, while at driving forces of 54 (Run 38) and 48 percent (Run 34) the drying time to 10 percent required 27 and 33 hours, respectively. Each of these runs was repeated several times. The rates of water removal under various solvent driving force schedules are shown in Fig. 6.

Normally, it would be expected that the most rapid drying rate would result by maintaining high solvent purity or concentration during the extraction cycle. As indicated, however, this does not appear to hold since faster drying rates were actually obtained by starting with diluted acetone. This apparent discrepancy may be due to the nature of the extractives present in tanoak. Upon analysis, it was found that the total hot water soluble extract amounted to 8.3 percent while the acetone solubles ran 4.9 percent (on a dry basis). Upon adding acetone to the aqueous soluble extract, considerable insolubles were thrown out of solution. This observation sug-

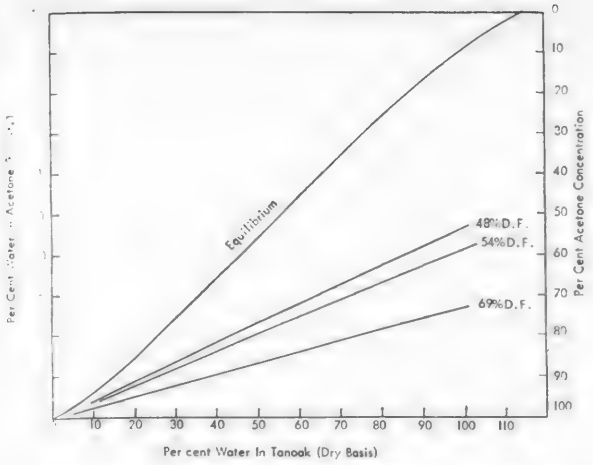

Fig. 5.—Various solvent concentrations greater than equilibrium; i.e., percent of driving force (D. F.).

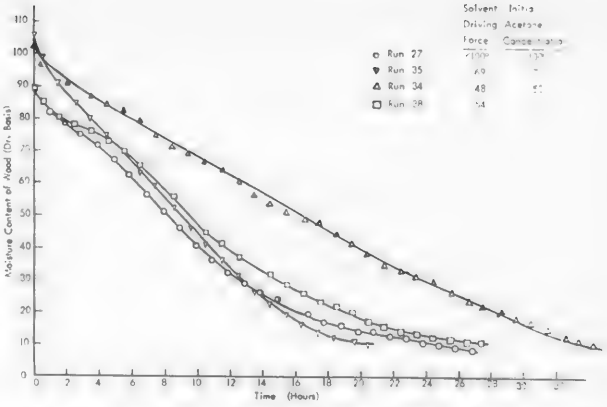

Fig. 6.—Rate of water removal at various acetone concentrations during solvent seasoning.

that the acetone insoluble extract may retard water removal from the green lumber when high purity acetone is used while starting the extraction cycle with an aqueous acetone solvent removed some of these interfering insolubles and hence speeded up the drying rate. In this connection, it was observed that extract yield from various runs was always higher when starting with dilute acetone. These yields ran about 75 pounds of extract per 1,000 board feet. The nature of this extract is under investigation.

The equilibrium and solvent driving force data will also be useful in setting up cascade operation procedure which would be used in a commercial solvent seasoning installation to make optimum use of the solvent prior to rectification. In such a system, the solvent from the driest charge would be sent to the extraction chamber unit containing the next driest stock and finally the solvent would be circulated over the freshest charge before going to the distillation unit for solvent recovery.

Table 3 also reveals that the extraction cycle was continued for an hour or more after the lumber had reached an average of 10 percent moisture content. At the close of the extraction cycle, the solvent was drained from the extraction chamber, then the solvent recovery cycle was started followed usually by a short steaming period to recover the acetone remaining in the lumber. These solvent recovery cycles varied from 4½ to 8 hours. The total solvent seasoning periods reported here varied from 29-2/3 to 41½ hours depending upon conditions used.

Solvent Retention

The final average moisture contents reported here are based on oven moisture determinations. Therefore, the values reported represent not only the moisture content remaining in the stock but would also include any residual acetone present in the material. The toluene distillation method for determining moisture content was not too satisfactory because of the distribution coefficient of the acetone between toluene and water in the graduated trap. The amount of acetone remaining in some of the dried lumber was determined by the hydroxylamine hydrochloride method (11). For this purpose, 1-inch cross sections were cut from various portions of the board, the cross sections were chipped and transferred to a distillation flask, water was added to cover the chips, followed by distillation. The acetone in the distillate was then determined in the usual manner using the above-mentioned hydroxylamine hydrochloride procedure. The lowest solvent retention values obtained amounted to about 2 percent (dry-weight basis). Since the moisture contents reported here are not corrected for acetone, the actual moisture contents are lower than represented in Table 3. Further experiments are planned to attempt to reduce solvent retention values. In the case of solvent seasoned ponderosa pine, acetone retention figures were reported to be as low as 0.3 to 0.6 percent.

Metals for Seasoning Unit

Another important point to establish was the effect, if any, of constructional metals such as iron if used for constructing a solvent seasoning unit for drying tanoak. For this purpose, several runs were made in which steel wool was put in the solvent circulating system. The presence of iron did not appear to have any effect, staining or otherwise, during these runs. Although only a few runs were made using iron, preliminary results would suggest that iron or steel would appear satisfactory as construction materials.

Seasoning Defects

The tanoak lumber from practically all the solvent seasoning runs was relatively free of seasoning defects and free of stresses (Fig. 7). The reason for this may be that no significant moisture gradient was found throughout the thickness of the solvent seasoned lumber. This would also indicate that water removal is accomplished by means of direct extraction throughout the thickness and length of the board, which would tend to minimize stresses rather than moisture diffusion from the core to the surface of the board. On occasion, a board would contain a small area or streak containing collapse; but this defect was believed to be due to the presence of heartwood or transitional heartwood.

Summary

Preliminary solvent seasoning runs indicated that 4/4 tanoak sapwood can be dried to 10 percent moisture content in less than 30 hour instead of many months as had been required with previously recommended procedures. The solvent seasoning process on

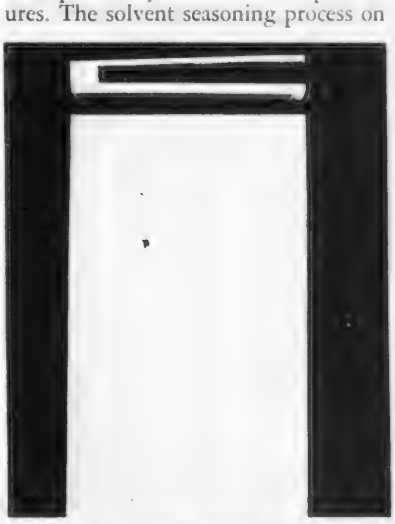

Fig. 7.—Solvent seasoned tanoak.

tanoak has still another advantage in that the lumber so processed is relatively free of seasoning defects, in contrast again to much of the material dried by conventional methods. It is planned to extend this investigation to such areas as the effect of other solvents on drying rates, lowering of solvent retention, and a chemical appraisal of the extract recovered as a by-product. Such information will be helpful in determining the possible merits of solvent seasoning as a commercial process for drying tanoak.

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New Hardwood Log Grades for Shoe-Last and Bowling-Pin Blanks

Fig. 1.—Bolts for last blocks and bowling pins are cut to size with a modern, hydraulically controlled slasher saw.

Fig. 2.—A hydraulically controlled bolter saw is used to cut bolts into shoe-last billets.

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Manufacturers of rough last blocks and bowling pins generally pay premium prices for relatively large, clear sugar maple logs that have wide bands of sapwood. In general, however, the tempo of the industry has left little time for manufacturers to thoroughly investigate the factors that affect log quality.

One manufacturer (Fitzpatrick and Weller, Inc., of Ellicottville, N. Y.) suspected that his log-grading system did not satisfactorily segregate logs into value groups; so he asked the U. S. Forest Service to help him make a quality study of the logs he was using. Since the Forest Service operates with wood-using industries in such studies of timber quality, the proposal was accepted.

[1] A contributed paper received June 195

[2] Numbers in parentheses refer to Literature Cited at the end of the report.

Fig. 3.—Rough shoe-last blocks are turned out on a modern pattern lathe. Note block pattern to left of bolt being turned.

Fig. 4.—Rough-turning a bowling-pin blank on an automatic lathe.

Objectives

To meet the needs of such a company, a satisfactory log-grading system (3)[2] should have the following performance standards:

- The system should separate from woods-run those logs suitable for the products.
- It should segregate these logs into value groups (grades) within which variability of individual log values would be reasonably small.
- The mean value of one grade should differ from that of the next higher grade by at least 15 percent, and these differences should be approximately equal.
- When applied to as few as 60 logs, the grading system should predict mean values to within 5 percent of the true value.
- It should have clear, understandable specifications, and these should be based on measurable and visible log characteristics that can be consistently applied by the company scaler after a limited period of training.

The objective of this study was to use these standards in checking the effectiveness of two grading systems:

1) The U. S. Forest Service hardwood log grades for standard factory lumber (5)
2) The company's log-grading system (table 5).

...d, if neither proved satisfactory, develop and test a new log-grading system especially adapted to last-block and bowling-pin production.

This new grading system is based on product yields from logs with different characteristics. With it, a company can predict with confidence the gross value of product from large or small lots of logs and establish appropriate prices for logs in each grade. With few modifications, the system could be applied to other specialty products.

A secondary objective was to establish guides for deciding which logs to use for each product. Scarce, expensive raw material must be used wisely. This can be accomplished best by proper allocation of raw material to two or more integrated enterprises. Failure to do so will result in lower product yield and increased manufacturing costs. In this case the cooperator was manufacturing shoe-last blocks, bowling-pin blanks, and standard factory lumber. With full knowledge of the factors affecting raw material fitness for each product, it should be possible to increase net returns from the over-all business.

Background

The manufacture of rough shoe-last blocks and non-laminated bowling-pin blanks occupies a relatively small but steady position within the primary wood-using industries of the Nation. Some 1½ million rough shoe-last blocks[3] are produced annually, 75 percent in the Northeastern States, the remainder in the Lake States. Most bowling-pin blanks are produced in Michigan, Wisconsin, and New York.

Production Methods: Rough-turned last blocks are manufactured in sizes ranging from 4 to 6-¼ inches in cross-section and 9-½ to 14-¾ inches in length. The dimensions of green rough-turned bowling pins are approximately 6 by 17 inches.

The raw material consists of selected sugar maple logs 8 to 16 feet long and generally 12 inches and larger in diameter. These logs are bucked into bolts the length of the desired blocks or pins (Fig. 1). The bolts are then sawed radially into wedge-shaped billets (Fig. 2). The billets are rough-squared; then they are rough-turned on pattern lathes into last blocks or bowling-pin blanks (Figs. 3 and 4). Rough-turned shoe-last blocks are generally dried to a low moisture content prior to shipment. Rough bowling pins are generally sold in a green condition.

[3] Last Block Manufacturers Association records.

Factors Affecting Yield: A great deal of the variation in quantity and quality of pins and last blocks that can be cut from a log is associated with visible log characteristics. The most important of these appear to be 1) log position—butt log or upper; 2) log diameter; 3) width of sound sapwood; and 4) log surface defects that indicate the pattern of blemishes in the sapwood.

It appears that log diameter and width of sapwood govern the *size* of blocks obtainable. Position of log in tree and amount of usable wood (clear material between larger knots, seams, holes, and unsound defects) affect both *size* and *number* of blocks or pins that can be recovered. Other blemishes in the usable wood—light bird peck, small pin knots, mineral stain, cross grain, and heart wood—affect the *quality* of the product.

These log factors are essentially the same as those that affect the quality of logs for producing standard hardwood lumber (v). However, there are differences. One is that log straightness is important in lumber production but not in producing such short products as last blocks are bowling pins. Another difference is the importance of sapwood in producing quality last blocks and bowling pins, a relatively unimportant factor in producing hardwood lumber.

However, certain principles of log grading are applicable in both cases. For example, in both cases log grades depend upon a grader's ability to determine from log surface abnormalities whether the usual underlying blemish is in the heart center or in the rim of wood surrounding it. (The heart center is the central cylinder in the log, in diameter 4/10 of the total log diameter.)

For last-block and bowling-pin production, blemishes include all of those considered in lumber production plus the occurrence of heartwood. But in both cases the suitability of a log is to a large extent determined by the arrangement of blemishes in the log, particularly with relation to the heart center. Thus simply using the Forest Service hardwood log grades for standard factory lumber might do a fairly good job of segregating logs into value groups for producing last blocks and bowling pins.

Of course log characteristics are not the only factors that influences the quality and quantity of products produced. Size of blocks or pins being produced is another factor.[4] Production methods and kiln-drying schedules are others. But a great deal of the variation in product yield is associated with log characteristics. And this source of variation was the subject of this study.

Scaling Practice: The cooperating manufacturer scaled logs with the Doyle log rule. He applied the rule without making the usual deductions for sweep and crook and unsound wood in the heart center. For block and pin production, this modification of scaling practice is reasonable. But such practices affect the scale and hence the product values per M feet log scale. The effect of such practices, and of using different log rules, must be taken into account in developing and using the grading specifications.

[4] Usually logs are processed into the largest popular sizes that can be practically obtained. Demand for extremely large last-block sizes is limited and is met by special order only. On the other hand, an appreciable amount of the smallest sizes are obtained by reworking larger worn-out lasts. This situation limits somewhat, the effect of block size on yield

Procedures

A sample of 101 logs, representing all size and quality classes, was selected for study. The sample make-up is indicated in Table 1.

In studies of this sort an adequate record of each log must be obtained to determine the importance of the various factors affecting log quality. This is best accomplished by measuring the position and size of each characteristic found on the log, and carefully recording it on a log diagram (4). This procedure was followed on each log in the sample. Furthermore, each log was scaled and graded according to both the Forest Service and Company systems. As each log was processed, the size and number of blocks and pins was recorded. From these data, the following results were obtained.

Results

Woods-Run Logs Suitable: One reason why the producer was interested in this study was the apparent lack of any relationship between weekly product values and log costs. So the first point checked was the possibility that certain logs were being utilized at a loss to the Company. But

Table 1.--Log sample by size and grade

Scaling diameter (inches)	Forest Service hardwood factory lumber log grade			Non-factory[1] grade
	1	2	3	
	Number	Number	Number	Number
10 to 15	11	15	11	9
16 to 19	8	10	8	5
20 and over	9	7	3	1

[1] Logs that did not meet minimum specifications for Factory Lumber Logs (1).

Table 2.--Comparison of pooled within-grade value variances of the grading systems applied to 101 sample logs

Grading system	Scaling practice	Pooled variance of value within grades[1]
Forest Service	International net	2126
	International modified gross	967
	Doyle--Company application	2395
Company	International net	2226
	International modified gross	1269
	Doyle--Company application	2964
New system	International net	766
	International modified gross	503
	Doyle--Company application	1593

[1] Variance formula:

$$PV = \text{Pooled } \frac{\sum f_i X_i^2 - \frac{(\sum f_i X_i)^2}{\sum f_i}}{\text{Pooled } (\bar{F}_i - 1)(\bar{F}_i)}$$

Where:

PV = Pooled variances

F_i = Number of logs in i^{th} grade

f_i = Log-scale volume of a given log in i^{th} grade

$\bar{F}_i$ = Log-scale volume of mean log in the i_{th} grade

X_i = Value per M board feet log scale of a given log in the i^{th}

$f_i X_i$ = Unit value of a given log in the i^{th} grade.

the study indicated that woods-run logs brought in under the Company's specifications were for the most part suitable for last-block and bowling-pin production. If purchased at going lumber-log prices, all of the study logs were marginal or better for last blocks.

Block and Pin Values: Last-block and bowling pin values were compared with lumber values for each sample log using published lumber-grade yield data for sugar maple factory-lumber logs (5), the lumber yield of several "below-grade" logs processed at the company sawmill, and Company price data for each product. In only one case did the potential gross lumber value equal or exceed that of the gross block and pin value of a log. This particular log contained shake in a critical area that severely lowered the yield of blocks but did not seriously reduce the potential lumber value. However, logs under 12 inches, and poor-quality logs over 20 inches in diameter, were so close to the line that it probably would have been wise to convert them into lumber.

Forest Service Grades: The study showed clearly that application of Forest Service hardwood log grades for standard factory lumber to last-block and bowling-pin logs resulted in unsatisfactory performance.

Excessive variation in values resulted when the Doyle log rule was used or when the International log rule was applied on a net basis (Table 2). With such variation, the number of logs needed to achieve reliable value estimates would be greater than that desired (Table 3).

The difference between product values of each grade was great enough, but it lacked the desired uniformity. The differences varied from 19 to 46 dollars per M feet net International scale, and was even greater when the Doyle rule was applied (Table 4).

When the International rule was applied on a relatively gross basis (ignoring sweep, crook, and unsound defect in the heart center) a fair degree of segregation was obtained, and the pooled within-grade variance was reduced considerably. The required sample size to obtain the desired accuracy of estimate was also reduced to about 60 logs for all grades except that group of logs that failed to meet the minimum specifications of the system (non-factory). The principal objections to the system under these conditions were the non-uniform value differences between grades and the exclusion of material that was suitable for the products manufactured.

Failure of this grading system to meet the performance standards desired when Doyle or net International log rules are applied can be traced to several factors. Because of the nature of the product, logs over 16 or 17 inches in diameter develop excessive waste in processing. Only the outer band of material (5 to 6 inches) is utilized. For example, in a 24-inch log a core of material 12 inches in diameter is wasted. The result is that, other factors being equal, value yield per M feet log scale is greatest for logs 14 to 18 inches in diameter.

The decrease in product value per M feet log scale for log diameters above 18 inches is more extreme when the Doyle Rule is used. Thus it appears that the best scaling system is the International rule applied on a modified gross basis.

Then too, the lumber log grades do not take width of sapwood into account. And minimum diameter requirements appeared to be on the high side for Grade 1 logs and too small for Grade 3 logs.

It was also noted that the majority of logs not meeting minimum factory-lumber log specifications were suitable for last-block and bowling-pin manufacture. However, this fault could easily be remedied by including these logs in an additional grade below that of Grade 3.

Table 3.--Sample size required[1/] by various log-grading systems and scaling practices--(Accuracy of ± 5 percent, 95 percent probability)

(Number of Logs)

Log grade or class	Scaling Practice		
	Doyle rule, Company application	International rule	
		Net	Modified gross
FOREST SERVICE GRADES			
No. 1	63	27	23
No. 2	89	78	58
No. 3	151	89	59
No. 4[2/]	139	139	101
COMPANY LOG-GRADE SYSTEM			
Select	131	75	65
No. 1	[illegible]	80	59
No. 2	127	96	56
No. 3	319	285	266
SUGGESTED NEW GRADING SYSTEM			
No. 1	21	25	11
No. 2	42	19	14
No. 3	95	57	37
No. 4	37	109	[illegible]

1/ Sample size formula - $n = \frac{t^2 s^2}{d^2}$

Where n = sample size
t = appropriate value of t
s = standard deviation
d = desired degree of accuracy

2/ "Below grade".

Table 4.--Gross block-and-pin values by the various log grades

(Dollars per M feet log scale)

Log grade or class	Scaling practice		
	Doyle rule, Company application	International rule	
		Net	Modified gross
FOREST SERVICE GRADES			
No. 1	$291	$291	$236
No. 2	251	216	207
No. 3	199	170	157
No. 4[1/]	193	151	141
COMPANY LOG GRADE SYSTEM			
Select	$254	$229	$221
No. 1	264	221	211
No. 2	190	178	163
No. 3	145	154	129
SUGGESTED NEW GRADING SYSTEM			
No. 1	$340	$269	$251
No. 2	256	222	214
No. 3	210	183	169
No. 4	151	137	122

1/ "Below grade".

Company Grades Also Inadequate: The Company log-grading system (Table 5), using the Doyle log rule on a gross basis, also failed to satisfactorily segregate the logs into product-value classes. Sample results indicated that the average product value of the highest-grade logs (Select) was less than that of the next lower grade (No. 1) by about $5.00 per M feet (Table 4). This is mainly because the Doyle log rule greatly underscales small logs.

The pooled within-grade variance of the Company system (Doyle log rule, Company application) was found to be appreciably greater than the lumber-log grading system, International gross or net. When the Company system was applied with the International rule (gross), variance was greatly reduced but was still excessive (Table 2); the sample size necessary to attain the desired accuracy was in excess of 60 logs for the highest and lowest grades (Table 3).

New Grading System Effective: The log diagrams of the sample logs were arrayed by gross-product values within diameter groups. From this array, misclassifications and erroneous predictions of the other systems were studied. By combining the strong points of these systems and recognizing several other log characteristics that were correlated with log quality, a new grading system was evolved.

The new system is based on the use of the International log rule on a modified gross basis; that is, no scale deductions are made for crook, sweep, or dote and decay in the heart center, provided a minimum of 4 inches of sound white wood is present in the peripheral zone of the log. Scaling deduction should still be made for sap rot, seams, splits, and other unsound defects in the peripheral zone of the log.

Logs as small as 10 inches can be processed profitably into shoe lasts. The value per M feet log scale increases as diameter increases up to about 16 inches; but beyond this point, log value per M feet log scale decreases because of the increasing volume of unutilized wood in the heart center of the log.

Number and position of log-surface and log-end defects are evaluated by the same techniques used with the Forest Service system for grading hardwood factory-lumber logs.

Because cuttings 1 foot long are utilized for last-block production, no apparent difference in product-value yield was observed between low line Grade 3 factory-lumber logs and below-grade logs having at least 50 percent yield in cuttings at least 1 foot long.

Table 6.--Suggested log-grading specifications for last-block and bowling-pin logs

(International 1/4-inch log rule, gross basis[1])

Grading factors		Log grade						
		Select		No. 1		No. 2		No. 3
Position in tree		Butts	Butts & Uppers	Butts	Butts & Uppers	Butts & Uppers		Butts & Upp
Diameter, scaling, inches		12-15	16-18	11 only	12+	11 only	12-20	10-11
Length without trim, feet		10+	10+	8+	8+	8+	8+	8+
Clear cuttings[2] on each of 3 best faces[3]	Min. length (feet)	7	5	7	3	3	1	2
	Max. number	2	2	2	3	2	No limit	No limit
	Yield in face length (min.)	5/6	5/6	5/6	2/3	2/3	1/2	1/2
Minimum sapwood requirement (depth in average radius), inches		5	6	5	5	4	4	No requir
Cull (rot, shake, heavy mineral stain, worm holes and bird pecks), maximum as indicated on log ends.		Permissible in not more than 1 quarter at each end or 2 quarters at one end of log within 5 inches of bark.						In not mor 2 quarter: each end Within 5 i of bark.

1/ No scale deduction made for sweep, crook, worm holes, bird peck, rot, dote or shake confined heart center as long as 4-1/2 inches or more of sound wood remains in peripheral zone of log.
2/ A clear cutting is a portion of a face free of defects (knots, overgrowths, holes, heavy bird peck, etc.) extending the width of the face (2).
3/ A face is 1/4 of the surface of the log as divided lengthwise.

The combined effect of these factors has been incorporated in the new grading system (Table 6). Basically it amounts to a modified version of the Forest Service hardwood log grades for standard factory lumber.

The new system performed satisfactorily on the sample logs involved in the study. We believe the performance will be the same on any other group of 60 or more logs. The pooled within-grade variances of the logs when graded by this system was much lower than for any other system, and the average values of each grade differed by at least 15 percent but by not more than 25 percent. Sample size necessary to obtain the desired degree of accuracy (± 5 percent) amounts to less than 60 logs for each of the four grades.

The specifications are concise and understandable. They are based on visible and measurable characteristics. although more comprehensive than those presently used by the Company,, they can with a limited amount of training be applied by the average log scaler.

Conclusion

The primary reason for undertaking this study was to test existing grading systems and, if these proved inadequate, to develop a better one. This was accomplished. This shows how a wood-using industry can develop adequate grading specifications with relatively little effort.

With the new grading system the Company can predict with confidence the gross value of products from large or small lots of logs. Combining this information with data on processing time and plant operating costs the Company is now able to establish appropriate prices for logs in each grade.

This information on net value differences between grades has also permitted the Company to make more accurate decisions as to which logs should be processed into bowling pins, which into last blocks, and which into lumber. For example, the Company is now processing small (10- and 11-inch) logs and large (over 20 inches) Grade 4 logs into standard lumber when lumber prices are favorable. The stumpage-buying policies have also been influenced by the study results.

With minor modifications, the procedures followed in this study could be applied to the development of improved specifications for industries manufacturing barrel staves, rough bobbins, wood handles, baseball bats, and other miscellaneous wood turnings.

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EFFECT OF FLAKE DIMENSIONS ON . . .

Properties of Particle Boards

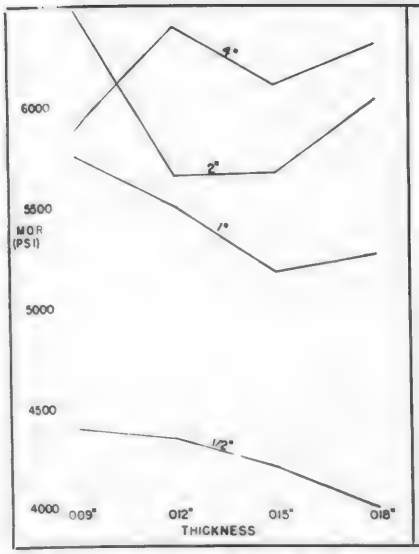

Fig. 1.—Modulus of rupture of boards from 4 flake lengths and 4 flake thicknesses. Values averaged to 0.75 specific gravity and 4 percent resin content.

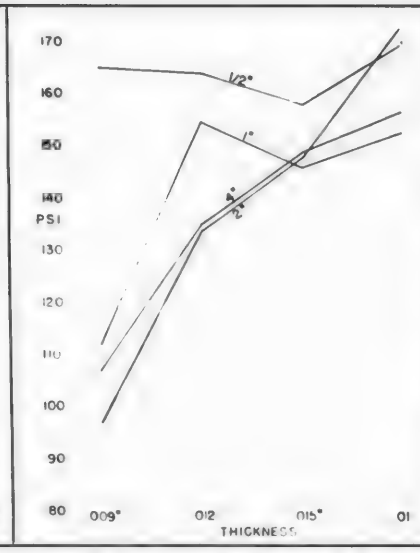

Fig. 2.—Internal-bond strength of boards from 4 flake lengths and 4 flake thicknesses. Values averaged to 0.75 specific gravity and 4 percent resin content.

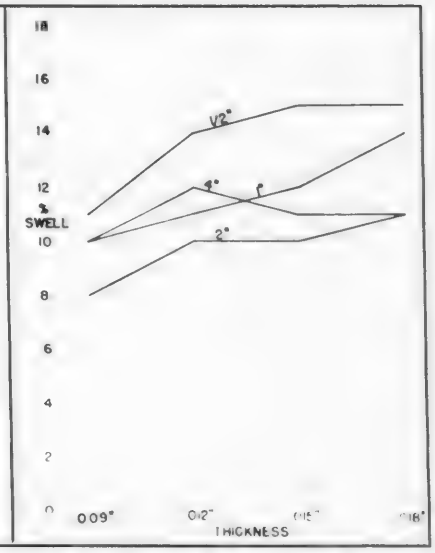

Fig. 3.—Percent thickness swell after 24 hours, of boards from 4 flake lengths and 4 flake thicknesses. Values averaged to 0.75 specific gravity and 4 percent resin content.

JAMES BRUMBAUGH

Washington State University, Division of Industrial Research, Wood Technology Section

IT IS WELL KNOWN THAT the use of flakes for manufacturing particle board from wood residue permits a high degree of utilization of the inherent strength of the wood. Although some research has been conducted in recent years to ascertain optimum flake geometry for the development of optimum bending strength,[2,3,4] the interrelationships of particle shape and a variety of board properties appear to require a more thorough investigation.

This study was undertaken to provide a more detailed picture of these interrelationships and to determine the applicability of published length-thickness ratios to a wider range of specific gravity and resin content, and to other physical tests in addition to bending strength. The design of the experiment therefore, incorporated 3 levels of specific gravity; 0.65, 0.75, and 0.85, together with 4 flake lengths; 1/2, 1, 2, and 4 inches, four flake thicknesses: 0.009, 0.012, 0.015, and 0.018 inches, and two levels of adhesive: 3 and 5 percent. This combination of variables provided an experiment having a 3 x 4 x 4 x 2 factorial design. Three replications of each treatment combination were em-

Flakes of 4 sizes were made into boards with 2 levels of resin and 3 levels of specific gravity. Long flakes produced high modulus of rupture; short thick flakes gave good internal bonds; long thin flakes promoted dimensional stability. Optimum length-thickness ratio was 150–250.

Presented at the Pacific Northwest Section Meeting February 1959, Coos Bay, Oregon.

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Table 1. Average physical properties of boards arranged to reveal the effect of flake length and thickness.

Flake Length, in.	Modulus of Rupture, psi	Internal Bond Strength, psi	Percent Thickness Swell 2 hr.	Percent Thickness Swell 24 hr.	Percent Water Absorption 2 hr.	Percent Water Absorption 24 hr.	Percent Linear Expansion 2 hr.	Percent Linear Expansion 24 hr.
½	4890	165	6	14	11	29	0.03	0.09
1	5420	141	5	12	10	26	0.02	0.08
2	5980	138	4	10	8	23	0.02	0.08
4	6160	137	5	11	8	24	0.02	0.07
Flake Thickness, in.								
0.009	5620	120	5	10	9	24	0.02	0.06
0.012	5470	147	5	12	9	25	0.02	0.07
0.015	5280	150	5	12	9	27	0.02	0.09
0.018	5420	163	5	13	9	27	0.03	0.09

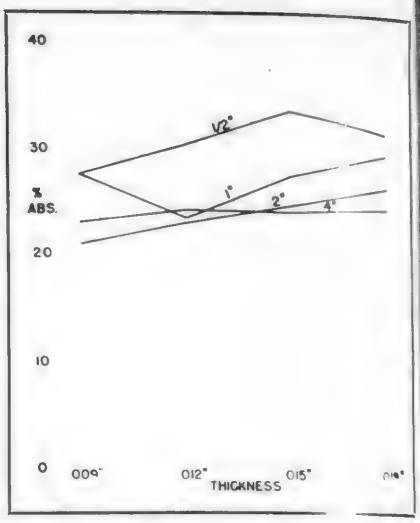

Fig. 4.—Percent water absorption after 24 hours, of boards from 4 flake lengths and 4 flake thicknesses. Values averaged to 0.75 specific gravity and 4 percent resin content.

ployed in order to provide a reasonable measure of the within-treatment variance.

The comparatively narrow range of flake thickness was intended to provide a closer study of the thickness range commonly used in most commercial plants.

Experimental Procedure

Flake Preparation

One-inch Douglas-fir lumber in the rough, green condition was obtained for the study. As a first step, the stock was crosscut into 4-inch lengths suitable for the laboratory flaker, and then segregated into 16 piles, each pile containing an equal amount of wood from each board. Subsequently, each pile was randomly assigned to be processed into one of the 16 combinations of flake thickness and length. After drying to a moisture content of about 5 percent, the 1-, 2-, and 4-inch flakes were passed over a vibrating screen with openings of 0.184 inch to eliminate the fine material. Fines from the ½-inch flakes were removed by passing the flakes over a vibrating screen with openings of 0.109 inch. Due to breakage in handling, it was found impossible to exercise control over flake width. It was noted, however, that the ½-inch long flakes averaged approximately ⅜-inch in width while the remaining flakes ranged from ¼ to 1 inch in width, the distribution being skewed toward the wider dimension.

Board Formation

Boards were made with Amres 7500, a liquid urea-formaldehyde adhesive, and Paracol 404N, a wax emulsion. Each batch contained a sufficient quantity of flakes sprayed with 3 or 5 percent resin and 1 percent wax to provide one board each of 0.65, 0.75, and 0.85 specific gravity (o.d. weight–o.d. volume). All boards were pressed in 15- by 15- by ½-inch sizes with the exception of those composed of 4-inch flakes which were pressed from 18- by 18- by ½-inch. mats. This latter procedure afforded a minimum of 3 inches for edge trim where the flakes tended to be oriented parallel to the edges of the felting mold. Preliminary testing had shown that the effect of this orientation extended in from the edges of the board a distance approximately equal to the flake length.

What This Research Means

Particle boards are produced from many sizes and shapes of wood particles, each with certain desirable features. This study shows that boards pressed from flakes exhibit diverse properties when various flake geometries are employed in the raw material. Long flakes enhance bending strength; short, thick flakes develop high internal bonds; long, thin flakes improve dimensional stability. A minimum length-to-thickness ratio of flakes in the range of 150–250 was necessary to achieve the maximum properties for a given flake geometry.

The manufacturer who knows the end use of his product, and therefore knows what board properties should be maximized, can utilize a particle geometry which will aid him most in attaining the desired properties.

The moisture content of each batch was measured before spraying and sufficient water was added with the resin and wax to elevate the moisture content of the board to approximately 11 percent at the time of pressing. Thermocouples placed midway between board surfaces as well as at the surface of preliminary panels indicated that a 9 minute press cycle at a platen temperature of 290°F. was adequate to bring the center temperature of the board into the curing range. The pressure cycle consisted of full pressure for 5 minutes followed by a decrease to 50 psi for the remainder of the pressing time. The maximum pressures were 250, 400, and 700 psi for boards of 0.65, 0.75, and 0.85 specific gravity.

Specimen Preparation and Testing

After pressing, the boards were conditioned to practiced equilibrium at 70°F and 50 percent relative humidity, and each board was sawn to provide two 3- by 12-inch specimens for static-bending tests, one 2- by 2-inch specimen for measurement of internal-bond strength, and one 3- by 9-inch specimen for the water-immersion tests.

Strength tests were conducted according to ASTM Designation D1037-56T, "Tentative Methods of Test for Evaluating the Properties of Building Fiberboards." The water-immersion specimens were immersed with the plane of the surface oriented vertically, and at intervals of 2 and 24 hours, water absorption, thickness swell, and linear expansion were tabulated.

For each combination of flake length and thickness, the data for each property were plotted against the actual specific gravity of the board, and a regression line was drawn for the purpose of picking off values at the desired specific gravities of 0.65, 0.75, and 0.85. Since there was 9 to 15 plotted points to determine each regression line, and since these sets of points had very little dispersion, eye-fitted line was used to determine regression.

Results

The average values of the physical properties for each length and thickness of flake are summarized in Table 1 and shown graphically in Figures 1 to 5. An analysis of variance conducted on the data derived from the regression lines indicated that there was no significant length-thickness interaction of flakes in any of the strength or water immersion tests. The absence of interaction permitted subsequent comparisons between any two flake thicknesses or lengths. The statistical significance of these comparisons are summarized in Table 2.

The effects of flake dimensions on board properties were consistent for both of the resin percentages employed and for the full range of specific gravity from 0.65 to 0.85, and, therefore, the data was condensed to eliminate these variables.

Table 2. Levels of significance between various combinations of flake dimensions using individual degrees of freedom.

Flake Length Comparison	Modulus of Rupture, psi	Internal Bond Strength, psi	Percent Thickness Swell 2 hr.	Percent Thickness Swell 24 hr.	Percent Water Absorption 2 hr.	Percent Water Absorption 24 hr.	Percent Linear Expansion 2 hr.	Percent Linear Expansion 24 hr.
Between 0.5 and 1 in.	.01	.05	N.S.	.01	N.S.	N.S.	N.S.	N.S.
Between 0.5 and 2 in.	.01	.05	.01	.01	.05	.05	N.S.	N.S.
Between 0.5 and 4 in.	.01	.05	.01	.01	.05	.05	.05	.01
Between 1 and 2 in.	N.S.	N.S.	N.S.	.01	N.S.	N.S.	N.S.	N.S.
Between 2 and 4 in.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Flake Thickness Comparison								
Between 0.009 and 0.012 in.	N.S.	.05	N.S.	.05	N.S.	N.S.	N.S.	N.S.
Between 0.009 and 0.015 in.	N.S.	.01	N.S.	.01	N.S.	N.S.	N.S.	.01
Between 0.009 and 0.018 in.	N.S.	.01	N.S.	.01	N.S.	N.S.	.01	.01
Between 0.012 and 0.015 in.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	.01
Between 0.012 and 0.018 in.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	.05
Between 0.015 and 0.018 in.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Discussion of Results

Modulus of Rupture

Thickness: The analysis of variance brought out no significant difference in modulus of rupture between boards made from the four thicknesses of flakes. Evidently, the increase in strength expected from a higher resin concentration on thicker flakes is offset by rougher flake surfaces and density fluctuations caused by poorer fitting of the thicker material.

Length: In comparing flake length, Table 2 and Figure 1 show that boards containing flakes ½ inch long developed bending strengths significantly poorer than the remaining boards. Although 1-, 2-, and 4-inch length comparisons were not significant, bending strength continued to increase as flake length increased over this range (Table 1).

It appears that short flakes have insufficient surface area to sustain or transmit the extreme shear stresses imposed on a flakeboard in static bending. Longer flakes have more surface area to withstand the shear stress and can "bridge" the area where the bending moment is greatest.

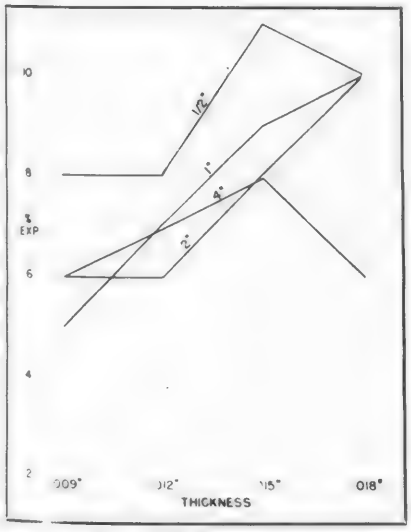

Fig. 5.—Percent linear expansion x 100 after 24 hours, of boards from 4 flake lengths and 4 flake thicknesses. Values averaged to 0.75 specific gravity and 4 percent resin content.

Internal Bond Strength

Thickness: The internal bond strength of boards incorporating flakes 0.009-inch thick was significantly less than that of boards utilizing thicker flakes (Table 2). Table 1 shows an additional increase in internal bond strength of the boards as flake thickness increases from 0.012 to 0.018 inch. This steady increase, although not statistically significant, can be attributed to the increased resin coverage of thicker flakes and the greater pressure necessary to form thicker flakes into boards of a given specific gravity, which results in better bonding of the flake interfaces. The average pressure for boards from 0.009-inch flakes was 412 psi, while 462 psi was needed for boards from flakes 0.018 inch in thickness.

Length: As shown in Fig. 2, boards manufactured from flakes ½ inch in length yield significantly higher internal bond strengths than boards containing longer flakes. On the other hand, there was no statistical differences in the strength of boards containing 1-, 2-, or 4-inch flakes. The superior internal-bond strength of boards composed of flakes ½ inch long may be due to the greater degree of internal discontinuity in the horizontal planes of the board. Instead of developing continuous planes of weakness which can precipitate early failure, as might be expected in a board containing 4-inch flakes, the former possess short, discontinuous planes which probably diminish a tendency to develop major areas of failure. Figure 2, which shows that boards made up from thin ½-inch flakes have an unusually high internal bond strength in comparison to boards made from thin but longer flakes, seems to indicate that the internal discontinuity factor is capable of maintaining high internal bond strength in spite of lower resin coverage.

Thickness Swell

Thickness: After 2 hours immersion in water, there was no signficant difference in thickness swell among boards containing flakes of the four different thicknesses. After 24 hours, however, boards made with flakes 0.009 inch thick swelled significantly less than those made from thicker flakes as shown in Figure 2. This could be a result of springback from a higher compression stress and accompanying compression deformation for a given density on the thicker flakes. Void spaces are also larger in boards made with thicker flakes since the flakes do not fit together as closely as do thinner ones. Apparently this characteristic allows water to penetrate into the board at a more rapid rate.

Length: Tables 1 and 2 show that at the end of 2 hours, boards with flakes ½ inch long developed significantly greater thickness swell than boards with flake lengths of 2 and 4 inches, whereas after 24 hours, boards with flakes ½ inch in length swelled significantly greater than any boards containing longer flakes. Furthermore, boards containing flakes 1 inch long had swelled significantly more than those with 2-inch flakes. It is probable that the increased swelling of short as compared to longer flakes can be attributed to a greater amount of end-grain surface available for rapid water absorption.

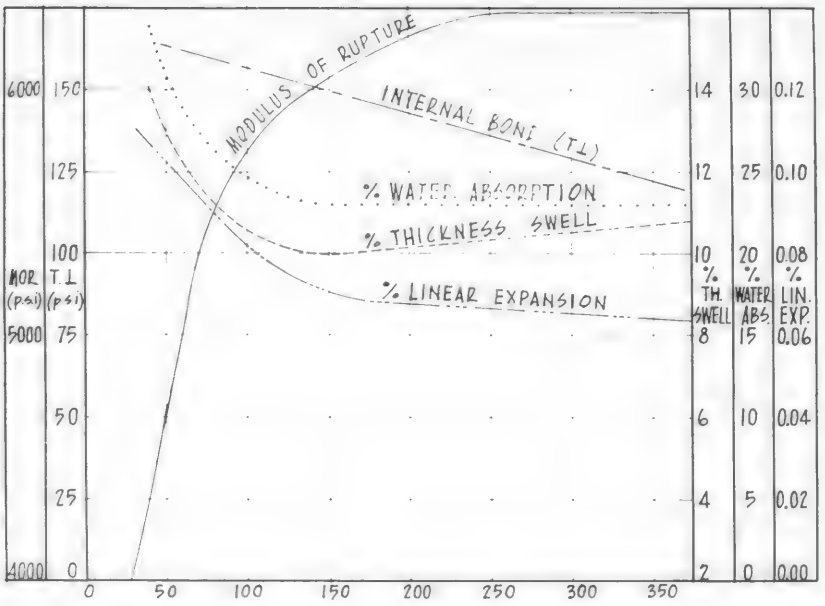

Fig. 6.—Composite curves of length-to-thickness ratio for each of five physical properties of Douglas-fir flakeboard.

Water Absorption

Thickness: There was no statistically significant difference among boards made from the four thicknesses of flakes after either 2 or 24 hours of water immersion. Table 1 shows, however, that at the end of 24 hours, the boards from thicker flakes had tended to absorb slightly more water than those from thin flakes.

Length: Boards composed of ½-inch flakes proved to have a significantly greater moisture absorption after both the 2- and 24-hour periods of water immersion when compared with boards made up of 2- and 4-inch flakes. The causes of the increased absorption of the boards formed from short flakes also can be explained on the basis of an increased amount of end-grain surface for rapid water absorption.

Linear Expansion

Thickness: Boards with thicker flakes had a significantly greater linear expansion than those containing thinner flakes as shown in Table 1.

Length: Boards with ½-inch flakes had a significantly greater linear expansion than those with 4-inch flakes. It was difficult to interpret logically the linear expansion data since equilibrium was not approached closely enough to cause well-differentiated effects. When wax is used, almost all the measurable linear expansion after 24 hours is due to the unrestrained swelling of the flakes at the edges of boards. Since the method of measurement employed in this project involved the external dimensions of the specimens, this edge effect apparently masked any differential expansion which might have taken place in the center portion of the specimens. The data therefore seem to correlate generally with the water absorption and thickness swell data simply because the wood which had the greatest absorption and greatest swell at the end of 24 hours also had the greatest expansion of flakes at the edge and consequently the greatest linear expansion.

Length-Thickness Ratio

Length-to-thicknesses ratios (L/T) as such, cannot completely predict the effect of flake dimensions on board properties. They merely reflect the combined effects of length and thickness, but are useful in determining at what point these effects reach a maximum and level off. Figure 6 shows the composite curves of L/T ratio vs. each of the five properties measured in this study. The slopes of the curves for ratio vs. board property were the same for each of the two resin contents and three density levels included in this study. Modulus of rupture increased as the L/T ratio increased, until the strength leveled off at an L/T of 200 to 250. This shows that modulus of rupture may be increased by either increasing flake length or decreasing flake thickness.

There was a steady decrease in internal bond strength as the L/T ratio increased, showing that internal bond can be increased by either decreasing flake length or increasing flake thickness.

Water absorption, thickness swell, and linear expansion decreased as the L/T ratio increased, until a ratio of 150 was reached, at which point the curves leveled off and no change occurred with increasing ratio of L/T. This shows that the water-immersion properties listed above can be aided by either increasing flake length or decreasing flake thickness.

Although the above description gives the general picture of the effect of L/T ratios on board properties, discrepancies arise when length and thickness are varied simultaneously.

For example, two types of flakes listed below have the same L/T ratios, but properties of boards from these two kinds of flakes varied in the following manner:

Property	¼ in.x 0.009 in.	1 in. x 0.01 in.
L/T	56	5
MOR	4400	528
Internal Bond	165	15
% Thickness Swell	11	1
% Water Absorption	25	5
% Linear Expansion	0.08	0

Boards from 1-inch flakes resulted in a higher modulus of rupture than boards from ½-inch flakes because the greater ability of the 1-inch flakes to withstand shear stresses and their greater resin coverage outweighed the disadvantage of their poorer fit.

In internal-bond strength, boards from ½-inch flakes were better than boards from 1-inch flakes because the effect of smaller planes of weakness outweighs the effect of poorer resin coverage.

In the water-immersion tests, boards from ½-inch flakes gave better results than boards from 1-inch flakes, indicating that even though the ½-inch flakes had twice as much end surface for absorption, some factor related to thickness, possibly goodness of fit, outweighed the length factor.

The fact that there were major discrepancies between different flake dimensions with similar L/T ratios suggets that when both length and thickness are changed simultaneously, a family of curves is created.

Conclusions

Within the range of thicknesses and lengths of Douglas-fir flakes studied in this investigation, the following conclusions may be drawn:

1. The use of longer flakes results in an increase in modulus of rupture whereas, shorter and thicker flakes have a favorable influence on internal bond strength.

2. The use of either long or thin flakes reduces thickness swell, water absorption, and linear expansion as measured after 24 hours immersion.

3. In order to obtain optimum overall board properties, the length-to-thickness of flakes ratio should be at least 200.

4. When length-to-thickness ratio is plotted against a given board property, varying flake length and thickness simultaneously creates a fan of curves.

Diffusion Through Air-Filled Capillaries of Softwoods—Part I: Carbon Dioxide[1]

HAROLD TARKOW AND ALFRED J. STAMM
Forest Products Laboratory,[2] Forest Service, U. S. Department of Agriculture

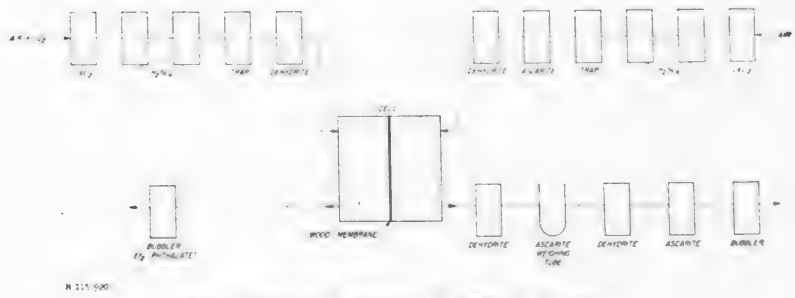

Fig. 1.—Schematic drawing of diffusion apparatus.

PHYSICALLY, WOOD IS MADE UP of an intricate network of capillaries whose individual components may vary in diameter from tenths of a millimeter down to angstroms, or a range from 10^{-2} to 10^{-8} centimeters. A complete understanding of the way moisture moves through wood requires an understanding of the way moisture moves in such capillaries. Stamm, using physico-chemical methods[3], has estimated the average dimensions of these capillaries in the simpler of the two kinds of wood, that is, the softwoods. He assumed, by analogy with an electric network, that the net diffusion across a piece of wood is that of a series-parallel network of capillaries each having a specific resistance to the diffusion. This specific resistance is determined by the effective area of cross section, the length of the capillaries and the reciprocal of the diffusion constant. In the case of those capillaries where air is present (lumen, pit chambers and pit membrane openings), he used the diffusion coefficient of moisture in air. In the case of those capillaries where air is not present (e.g., those created by the adsorption of moisture by wood substance) the diffusion coefficient used was that of moisture through wood substance. The latter has been recently investigated in the fiber direction[4]. This paper reports measurements of the diffusion of carbon dioxide in the air-filled capillaries. Such diffusion should be related to that fraction of the overall moisture diffusion which moves as vapor through the air-filled cavities.

Calculated D_{CO_2} in the transverse direction is about 30 times the observed value. In the fiber direction, both values were of the same order. For vapor diffusion in the fiber direction, the main seat of resistance is in the cell cavities rather than the pit system.

Principle of Method

The different types of capillaries are simultaneously active when moisture diffuses through wood. This makes it difficult to study directly the diffusion of moisture through the air-filled capilliaries without the contribution of its diffusion through wood substance.

Dry carbon dioxide gas does not swell wood; consequently its diffusion through dry wood occurs along the same pathways taken by that fraction of moisture which diffuses only through the air-filled capillaries. If one knows the diffusion coefficients of carbon dioxide and water vapor in air per unit dimensions of air (hereafter called the bulk diffusion coefficients) and if the assumption is made that the ratio of these values is the same as the ratio of the corresponding diffusion coefficients in the air-filled capillaries of wood per unit dimensions of wood (hereafter called D_{co_2} and D_{H_2O} vapor), then from a knowledge of D_{co_2}, D_{H_2O} vapor can be calculated. (See Part II). The experimental procedure was that of measuring D_{co_2}.

Apparatus

Figure 1 is a schematic drawing of the apparatus. The cell consists of two circular compartments 1 centimeter deep and 19.6 square centimeters in area. These were separated by the wood membrane and suitable gaskets. The edge of the cell assembly was taped with aluminum foil, which in turn was liberally coated with a rosin-beeswax mixture to prevent losses due to end-grain penetration. The cell assembly was suspended in a copper box having a bolted-down lid. The box was then immersed in a thermostatted bath (± 0.05° C.). Extending up through the lid were tubes leading to and from each cell compartment. Air dried over sulfuric acid and dehydrite and containing carbon dioxide at a known partial pressure was passed through one compartment. Dry, carbon dioxide-free air was passed through the other cell compartment. Both streams flowed at a rate of 90 cubic centimeters per minute. Higher rates were without effect on the transverse diffusion values. For longitudinal diffusion, rates of about 120 cubic centimeters per minute, together with a reduced area of diffusion, were necessary to attain steady-state diffusion. The carbon dioxide that diffused through the wood was swept up by the carbon dioxide-free air steam and carried along through a tube of dehydrite and into a weighing tube containing ascarite of absorb the carbon dioxide. The air stream was then vented to the atmosphere through a second ascarite tube in series with a diethylphthalate bubbler to prevent back diffusion of carbon dioxide from

Authors: Harold Tarkow, a research chemist, holds a PhD. from the University of Wisconsin. He has been with the USFPL since 1[illegible] concentrating primarily on dimensional stabilization and adhesion. Alfred J. Stamm, formerly a subject matter specialist at the USFPL, holds a Ph.D. from Wisconsin. He is now on the faculty of North Carolina State College.

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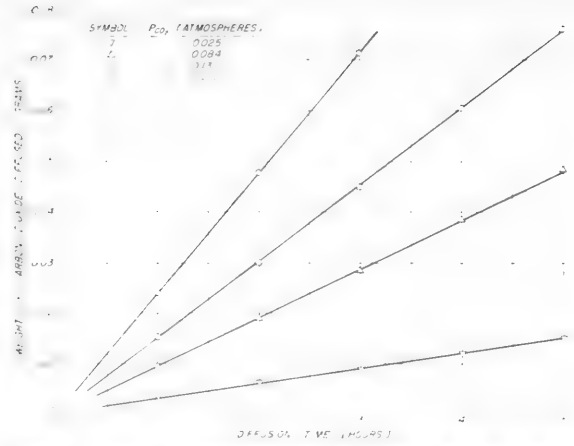

Fig. 2.—Effect of partial pressure of carbon dioxide, P_{CO_2} on the diffusion rate through 1/32-inch radially sliced Sitka spruce veneer.

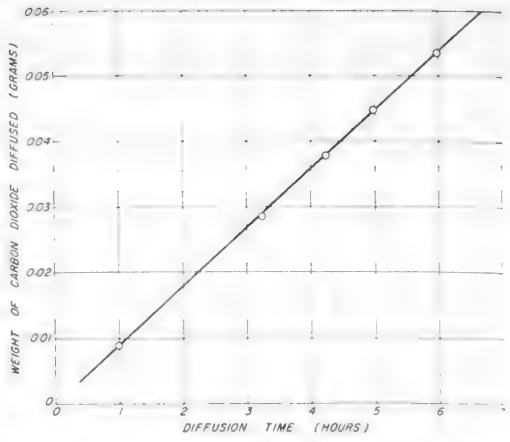

Fig. 3.—Rate of carbon dioxide diffusion through 1/10 inch radially sliced Sitka spruce veneer at 25° C. and a partial pressure of 0.21 atmospheres.

the air. Air-carbon dioxide mixtures were prepared by filling a gas cylinder with air at 75 pounds per square inch and admitting carbon dioxide from an adjoining cylinder. Analysis was made with a conventional gas analyzer. Before entering the compartments, each gas stream passed through several turns of copper coil in the water bath to bring the air to equilibrium temperature. Each compartment was connected to a leg of a diethylphthalate manometer. By controlling the depth in each bubbler at the exits, the total pressure in each compartment could be varied. A zero total pressure drop was maintained across the membrane; thus the only gradient was a carbon dioxide partial pressure gradient. The actual total pressure in each compartment corresponded to 2 centimeters of diethylphthalate, or about 2 millimeters of mercury in excess of atmospheric pressure.

Diffusion of Carbon Dioxide through Dry Wood

Transverse Diffusion: The wood consisted of 1/32-inch and 1/10-inch thick high-grade, radially sliced Sitka spruce heartwood veneer. Diffusion thus occurred in the tangential direction. The steady state was reached very soon after the experiment was begun, usually within an hour. The cumulative amount of carbon dioxide diffusing through the wood was plotted against time in hours. From the slope of the curve D_{co_2} was calculated, using the following approximate form of Fick's equation[3]:

$$D_{co_2} = \frac{gm.}{3600t} \times \frac{a}{A} \times \frac{1}{g./cc.} \quad (1)$$

in which *gm.* is the weight (grams) of gas diffusing through the wood in *t* hours; *a* is the thickness of the membrane in centimeters; *A* is the area of diffusion in square centimeters; and *g./cc.* is the concentration of carbon dioxide in the gas stream in grams per cubic centimeter.

Effect of Partial Pressure of Carbon Dioxide. D_{CO_2} was determined at 25° C. under different partial pressures of carbon dioxide using the same piece of 1/32-inch veneer. Figure 2 shows the diffusion-time plots. The following tabulation gives the D_{co_2} values for different partial pressures calculated from equation (1).

P_{CO_2} (Atmospheres)	D_{CO_2} (10^{-5} cm.²/sec.)
0.025	7.6
.084	7.3
.131	7.3
.210	7.2
	Average—7.4 ± 0.2

The values are essentially independent of P_{co_2} and thus show the validity of Fick's law.

Effect of Veneer Thickness. Figure 3 shows the diffusion-time plot for 1/10-inch-thick veneer. The corresponding D_{co_2} is 7.9 x 10^{-5} square centimeters per second. Considering the variability of wood, (density and morphology), a comparison of this value with the above average value (threefold difference in veneer thickness) indicates that D_{co_2} is virtually independent of veneer thickness. This, too, confirms the applicability of Fick's law.

Effect of Temperature. Figure 4 shows the diffusion of carbon dioxide through another sheet of veneer at two temperatures. The D_{co_2} values are 6.3 x 10^{-5} and 6.8 x 10^{-5} square centimeters per second at 25° and 35° C., respectively. The effect of temperature is in the anticipated direction. Since the temperature coefficient is so small, it can be concluded that the diffusion is not an activated one.

Reproducibility. The above tabulation shows the reproducibility of values of D_{co_2} for the same veneer specimen. The following shows the reproducibility for different veneer specimens. The letters following each value stand for a particular section of Sitka spruce veneer. All were 1/32-inch thick, except D, which was 1/10 inch.

25° C. (10^{-5} cm.²/sec.)	30° C. (10^{-5} cm.²/sec.)	35° C. (10^{-5} cm.²/sec.)
6.3 (A)	6.6 (E)	6.8 (A)
7.4 (C)	8.2 (B)	7.8 (C)
7.9 (D)	7.5 (F)	
	8.4 (G)	

The greatest variation at a given temperature of D_{co_2} is 27 percent, illustrating the appreciable variability even among well-matched specimens of veneer.

Comparison of Observed Values of D_{CO_2} with the Value Calculated from Stamm's Equation. According to Stamm[3], the transverse diffusion coefficient for the passage of a non-swelling gas through a softwood is given by the equation.

$$D_{gas} = \frac{1}{\frac{1}{D_w'} + \frac{n}{D_w''} \times \frac{l_m}{q_p} + \frac{n}{D_s'''} \times} \quad (2)$$

where *n* is the average number of fibers traversed per centimeter in the tangential direction (300); l_m is the average thickness of the double wall (7.2 x 10^{-4} cm. for wood with a specific gravity of 0.365, moist

WHAT THIS RESEARCH MEANS

This research shows that presence of a pathway in wood along which nonswelling vapors can diffuse. It is suggested that when moisture diffuses through wood, that component, due to water vapor, moves along this same pathway. In the transverse direction, the diffusivity along this pathway is much smaller than that calculated on the basis of capillary dimensions. This is ascribed to the small size of the openings in the pit membranes relative to the mean free path of a diffusing gas molecule.

[3] Barrer, R. M. 1941. Diffusion in and through solids. Cambridge Univ. Press.

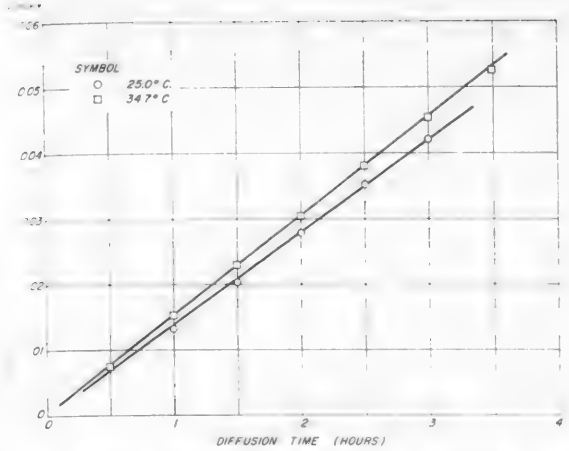

Fig. 4.—Effect of temperature on the rate of diffusion of carbon dioxide through 1/32-inch radially sliced Sitka spruce veneer at a partial pressure of 0.14$_6$ atmospheres.

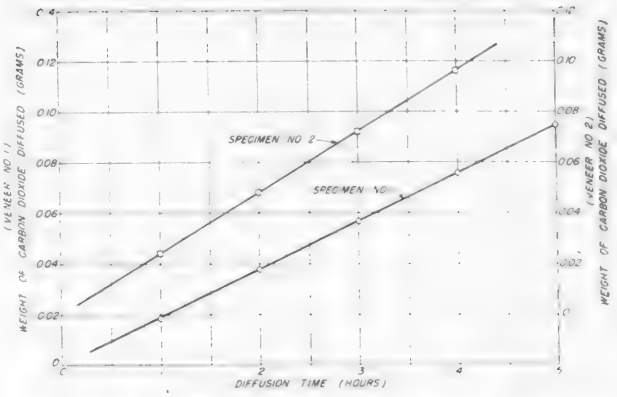
SPECIMEN NO 2
SPECIMEN NO
WEIGHT OF CARBON DIOXIDE DIFFUSED (GRAMS) (VENEER NO 1)
WEIGHT OF CARBON DIOXIDE DIFFUSED (GRAMS) (VENEER NO 2)
DIFFUSION TIME (HOURS)

Fig. 5.—Rate of diffusion of carbon dioxide through Sitka spruce in the fiber direction at a temperature of 30° C. Cross sections 2.83 cm.^{2} in area and 1.02 cm. thick. Specimen No. 1 $P_{co_2} = 0.020$ atmospheres; Specimen No. 2 $P_{co_2} = 0.029$ atmospheres.

free weight and green volume); q_p is the fractional area of the tangential walls of fibers covered with pits (0.014) l_p is the average thickness of the pit membrane (1×10^{-4} cm.); q_t is the effective fractional cross sectional area of the permanent pit membrane pores for the transverse direction (5.2×10^{-4}); D_o', D_o'', and D_o''' are the bulk diffusion coefficients of carbon dioxide in air in the fiber cavities, the pit chambers and in the pit membrane pores, respectively.

The equation assumes a particular series-parallel combination of conducting elements each characterized by a physical dimension, a measure of its abundance, and by the diffusion constant of the gas in the air within the element. Stamm assumed that these three values of D_o are equal to each other, and equal to the bulk diffusion constant of carbon dioxide in air. With these assumptions, equation (2) gives

$$D_{gas} = 0.0135\ D_o \qquad (3)$$

The bulk diffusion constant of carbon dioxide in air according to the International Critical Tables is 0.17 square centimeter per second. This gives a calculated D_{co_2} values of 2.3×10^{-3} cm.^{2}/sec. in the tangential direction which is about 30 times larger than the observed value.

Diffusion in the Fiber Direction

The Sitka spruce (heartwood) specimens used in these experiments were 1.02 centimeters thick in the fiber direction. The diffusion in the fiber direction, even at low P_{co_2}, was so rapid that the air streams could not be circulated fast enough across each face to maintain a steady diffusion state. Accordingly, the specimen was sandwiched between two brass plates, each having a circular hole in the center which reduced the effective diffusion area from 19.6 to 2.83 square ceintimeters. The steady state was now readily maintained. The extremely high ratio of diffusion in the fiber direction to that in the transverse direction assures very little error due to lateral spreading. Figure 5 shows the plot of the diffusion rate for two specimens. From the slopes of these curves the values for the diffusion coefficient in the fiber direction are found to be 5.6×10^{-2} and 4.7×10^{-2} square centimeters per second; average, about 5×10^{-2} square centimeters per second.

The passage of a nonswelling gas through wood in the fiber direction according to Stamm's equation is

$$D_{co_{21}} = 0.655\ D_o \qquad (4)$$

for wood with a specific gravity of 0.365 (moisture-free weight and green volume). Substituting 0.17 square centimeter per second for D_o

$$D_{co_{21}} = 11 \times 10^{-2}\ \text{cm.}^2/\text{sec.}$$

This calculated value is only two times larger than the above observed average value.

Discussion

In the transverse direction, the calculated D_{co_2} is about 30 times larger than the observed value. In the fiber direction, the observed and calculated values are of the same order of magnitude. What is the explanation for this highly significant difference?

Consider first the transverse D_{co_2}. In calculating the value from equation (2), it was assumed that the bulk diffusion coefficient of carbon dioxide in the cell cavities, pit chambers, and pit membrane pores is identical with the normal value, 0.17 square centimeter per second. This is probably true for the first two structures, but it is questionable whether the value for the pit membrane pores is the same as the normal value. The average radius of these pores is about 3×10^{-6} centimeters[3], whereas the mean-free path of a carbon dioxide molecule (under the diffusion conditions) is about 6×10^{-6} centimeters. Since the mean-free path is larger than the capillary radius, carbon dioxide can no longer behave as a normal diffusing gas. Its properties are influenced by the very frequent collisions with the walls. At each collision, a carbon dioxide molecule remains adsorbed for a while and then is desorbed in a random direction. The result is that the net diffusion rate along the capillary is reduced. The kinetics of the movement of gas molecules in such capillaries has been treated by Kundsen[5]. Returning to equation (2), assume that the bulk diffusion coefficient of carbon dioxide in the fiber cavities and in pit chambers is the normal value (0.17). What must be the value of the bulk diffusion constant in the pit membrane pores, in order to obtain the observed value of D_{co_2}? Substituting in equation (2), the bulk diffusion coefficient in the pit membrane pores is found to be 4.3×10^{-3} square centimeters per second. This is smaller than the normal bulk value by a factor of 40. This factor is

approximately that by which the observed overall diffusion constant is lower than the calculated value (actually 31). This indicates that for transverse vapor diffusion, the main seat of resistance is in the pores of the pit membranes.

Now consider the longitudinal values for D_{co_2}. Allowing for the variability of wood, one can conclude that the observed and calculated values of D_{co_2} are in reasonable agreement. This may seem puzzling, since pits are also involved in longitudinal movement. However, it can be shown that even if the abnormally low value, 4.3 x 10^{-3} square centimeters per second, is used for the bulk diffusion constant in the pit membrane pores in the equation from which equation (4) was derived[2], the effect on the calculated value of $D_{co_{21}}$ is negligible; in other words, for vapor diffusion in the fiber direction the main seat of resistance is not in the pit system, but rather in the cell cavities.

Conclusions

Measurements of the diffusion coefficient of dry carbon dioxide gas through the microscopically visible capillary structure of wood in the tangential direction have shown that the value is much smaller than the theoretical value calculated by Stamm using the analogy of diffusion with electrical conduction in a combination of series and parallel paths and by assuming that all diffusion is free bulk diffusion. This latter assumption is still believed to hold for passage of the gas through the fiber cavities and pit chambers but not through the pit membrane pores. This is a reasonable conclusion in view of the fact that the effective size of the pit membrane pores is smaller than the mean-free path of the gas at atmospheric pressure. The resistance to the passage of gas molecules through the very small pit membrane pores is shown to be 40 times what it would be under free diffusion conditions.

In the fiber direction the measured diffusion coefficient is of the same order of magnitude as the theoretically calculated value. This is shown to be due to the fact that the fiber cavities rather than the pit membrane pores furnish the major part of the resistance to diffusion.

Decay Resistance of Baldcypress Heartwood[1]

R. N. Campbell and J. W. Clark

Forest Products Laboratory,[2] Forest Service, U. S. Department of Agriculture

Decay resistance of baldcypress reputedly varies with origin and color. To check this, trees from the 4 principle growing areas and 7 localities were evaluated for natural decay resistance by soil-block tests with 4 fungi. Only 1 tree out of 27 showed the high resistance for which baldcypress is noted.

THE HEARTWOOD OF BALDCYPRESS (*Taxodium distichum* (L) Rich.) has long been known as a durable wood (*4,13,14*).[3] There are many examples of its extremely long service life in conditions of high decay hazard. Mattoon (*4*) cites cypress shingles lasting 50 to 100 years, fence posts in good condition after 40 years, and plantation buildings in excellent condition after 100 to 200 years. Another author (*12*) tells of cypress shingle roofs in service for 250 years and a grave marker in the ground for 160 years.

The decay resistance of baldcypress has been attributed to an extractable substance called cypressene (*6*), but there probably are other fungus-inhibiting chemicals in the wood.

Because of its renowned durability, baldcypress heartwood has been the preferred wood for such uses as greenhouse construction, exterior trim, porches and steps, tanks, vats, and fences. In most cases, these products need substantial protection against decay, and also are best made with wood that is easily worked and has little tendency to split or warp.

In the baldcypress lumber trade, several types of wood are recognized, such as tidewater red cypress, yellow cypress, white cypress, black cypress, and gulf cypress. These names generally are identified with the area of origin, as are the trade names tidewater and upland. All of these types belong to one botanical species, *T. distichum*. Originally red and yellow appear to have referred to the wood color prevalent in a region or locality. White and black were terms used by loggers, at least along the Atlantic coast, to denote logs that floated high (white cypress) and logs that floated very low or sank (black cypress). However, along the gulf coast black referred to color more than to buoyancy (*4*).

Mattoon (*4*) stated that cypress heartwood was darkest in color in the gulf and South Atlantic region and was lighter in trees to the north, up either the Mississippi Valley or the Atlantic coast. Although one color might predominate in a region, wide variations occurred within specific localities. He reported, for example, that cypress from swamps of the

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[1] A contributed paper received November 16, 1959.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Underlined numbers in parentheses refer to Literature Cited at the end of this report.

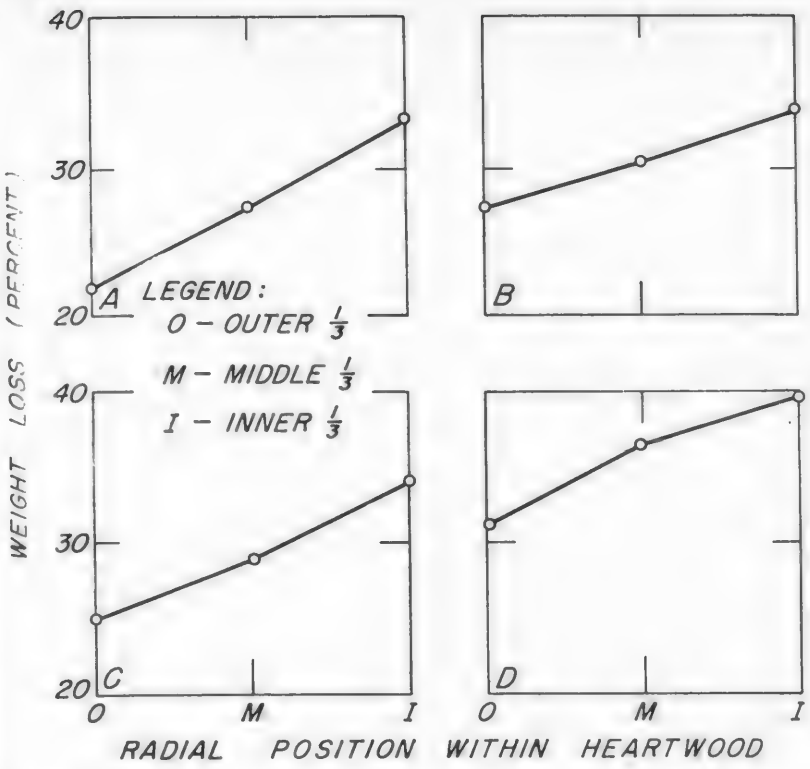


Fig. 1.—Average weight loss in percent caused by the four test fungi in heartwood test blocks of baldcypress from various radial positions within the tree, grouped by age classes. A, represents 6 trees 400 or more years old; B, 7 trees 200 to 399 years old; C, 10 trees 100 to 199 years old; D, 4 trees 99 years old or less.

Johns River averaged an amber or light orange brown and was called yellow cypress. Nearby in shallower swamps, the cypress wood was decidedly darker. These observations pertained to virgin timber; it is not known to what degree they apply to the second-growth timber constituting the bulk of the baldcypress cut today.

Suppliers of baldcypress wood have claimed that its decay resistance varies according to the locality or origin and to the assigned trade name. For example, it has been widely asserted that the most durable baldcypress wood is that cut from red cypress timber growing fairly close to salt water. "Experience has shown", Von Schrenk (*14*) commented in 1931, "that maximum length of life is to be anticipated from slow-growing darker colored trunks of trees which grow near tidewater."

The Forest Products Laboratory has received numerous inquiries about the matter, and, as there are no data supporting these claims, the investigation reported here was made to determine whether they have any foundation in fact. In addition to color types, the work involved the effects of environmental and physical factors known to be correlated with decay resistance in other timber species, such as locality of origin, tree age and size, and position of wood within the tree. A few samples of a baldcypress variety, pondcypress (*T. distichum* var. *nutans* (Ait.) Sweet), were also tested.

Procurement and Preparation of Samples

Trees were sampled in various size classes growing in tidewater and upland swamps of Louisiana, Mississippi, Florida, and South Carolina, which represent the principal areas of baldcypress production in the United States. The samples, in the form of disks 6 to 10 inches thick, were taken in each case from the upper end of the first 16-foot log. The samples and field data were obtained by personnel of the Southeastern and Southern Forest Experiment Stations.[4]

The approximate age of the trees was determined in most cases by counting the growth rings of the disks. In the first seven disks received, no ring counts were made, and the ages of these trees were based on estimates made at the time of felling. There is a degree of inaccuracy even in the age estimates made from the ring counts on the disks, since the disks were taken 18 to 20 feet above the ground; moreover, cypress often has false annual rings. The error from these sources is not sufficient, however, to interfere with the desired comparisons.

Test blocks in duplicate (1 by 1 by 3/8 inch in the grain direction) were taken for exposure to each fungus from the outer (O), middle (M), and inner (I) thirds of the heartwood of each disk along three different radii —the longest, the shortest, and one of intermediate length. In the outer heartwood an additional pair of blocks was taken along a fourth radius. Thus, the test results for each disk are based on data for 80 separate samples, a set of 20 for each of four test fungi—consisting of six each from the middle and inner heartwood zones and eight from the outer heartwood.

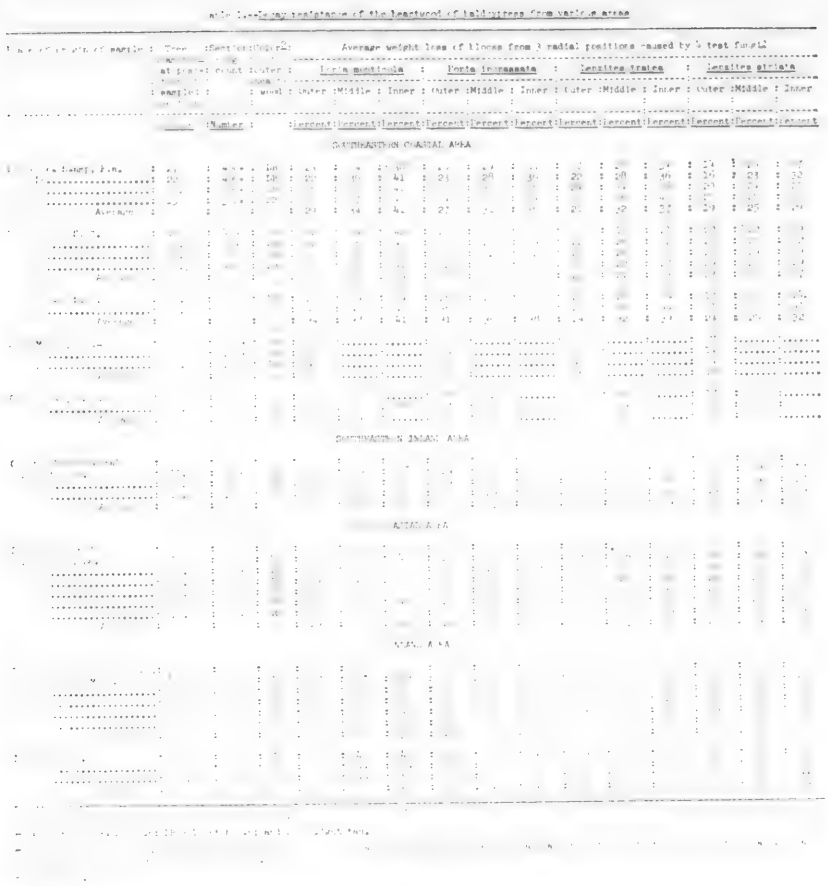
The blocks were rated on their radial faces for color and number of rings per inch. Four color classes were recognized: (1) Red, in which both springwood and summerwood had a decided pink color; (2) overall dark to medium brown, with the summerwood being dark brown to pink and the springwood light brown; (3) overall light brown to tan; and (4) light tan, with the springwood being light tan to cream colored and the summerwood having only a slight brownish cast.

Testing and Rating Decay Resistance

The soil-block technique (*1*) was used in making the laboratory tests for decay resistance.[5] Four decay fungi were employed: *P. monticola* (Madison 698), *P. incrassata* (Madison 563), *L. trabea* (Madison 617), and *L. striata* (103133–Sp). The first three fungi are prominent wood rotters that have been used extensively in tests of natural decay resistance (*2,3,5,7,9*). Moreover, records at the Forest Products Laboratory show that all three species have been isolated from rotting baldcypress wood in service. The isolate of *L. striata*, although not a regular test fungus, was included because it had been obtained from baldcypress.

[4] The authors are indebted to M. A. Taras, Southeastern Station, and A. F. Verrall and D. L. Fassnacht, Southern Station, for the field samples, and to T. C. Scheffer, USFPL, for assistance in analyzing the results.

[5] Except for a difference in test block size and the absence of preservative treating procedures, the technique was the same as described in ASTM Standard D1413-56T.



The tests were carried out in the usual manner in 6-ounce, wide-mouth, French-square bottles. To serve as the substrate for the fungus, the bottles were half filled with loam soil at a moisture content of 46 percent; a feeder strip of southern pine sapwood 1-½ by 1-⅛ by ⅛ inches in size was placed on top of the soil. The bottles thus prepared were sterilized and each was inoculated with the chosen fungus. Three weeks later the test blocks, which had been steamed for 30 minutes at 212° F., were placed on the fungus-covered feeder strips, where they remained for 12 weeks. The test bottles were kept in a room maintained at 70 percent relative humidity and 80° F.

The measure of decay was the percentage weight loss incurred by the individual test blocks, as determined from the original and final weights of the blocks when conditioned to approximately 12 percent moisture content.

As a final step of appraisal, the test material was rated according to classes of decay resistance indicated by the amounts of decay. The same classes, ranging from very resistant to nonresistant, have been used in a number of laboratory tests of the natural decay resistance of wood (*2,5,7,8,9,10*), and ratings on this basis have been in generally good agreement with the reputations of the woods for decay resistance.

Originally the classification scheme was based largely on results obtained with black locust (very resistant), white oak (resistant), and Douglas-fir (moderately resistant) in connection with a study in 1947 of tropical woods (*8*). Subsequent to this study the scheme has proved to be adequate without alteration for all woods that have been tested. It is designed as follows:

Decay Resistance	*Weight Loss in Test (Percent)*
Very resistant	0–10
Resistant	11–24
Moderately resistant	25–44
Nonresistant	45 or more

Since different test fungi vary in their capacity to cause decay, resistance ratings by this scheme are dependent on the specific fungi used.

Results and Discussion

The number of trees sampled, their source area, and weight losses from decay in the soil-block test are summarized in table 1. Table 2 shows the percentages of sampled trees that had outer heartwood with various classes of decay resistance. It may be noted that wood samples from most of the baldcypress trees were either resistant or moderately resistant, with the greater tendency being toward moderate resistance—especially to decay by the two *Poria* species. About 15 percent of the trees could be classed as having very resistant outer heartwood for decay by *L. trabea,* 4 percent for decay by either *P. incrassata* or *L. striata,* and none for decay by *P. monticola.* The limited amount of very resistant wood was unexpected in view of the reputation of baldcypress for high decay resistance. The results are, nevertheless, considered to be representative, since the test was standard in all respects and seemed in no way excessively severe. A trop[illegible] wood of high decay resistance incorporated in the same test was mildly attacked—as shown by weight losses ranging below 7 percent with the severest test fungi.

The pondcypress was not sampled sufficiently to permit similar appraisal, but it appears from the weight losses (table 1) to have been at least as resistant as the average baldcypress sampled.

The data of table 1 do not show regional or locality differences of practical significance in the decay resistance of heartwood from trees now being cut. Although decay resistance and color of the heartwood appear to be related, as indicated by the data in table 3, it is evident that the relation is too slight for color to be a useful guide, except possibly for wood that could be classed as "red." Outer heartwood classified as "red" had high decay resistance, but wood of this color was found in only one of the trees sampled. All outer heartwood classified as light brown to light tan consistently fell in the moderate decay resistance class (25 to 45 percent weight loss), except for one pondcypress sample that had an average weight loss of 23 percent. Outer heartwood samples of a majority of the trees were dark to medium brown and ranged from resistant (11 to 24 percent weight loss) to moderately resistant. In the latter color group, 24 percent of the samples were resistant when tested with *P. monticola,* and 4 percent were resistant when tested with *P. incrassata.*

In view of these findings largely second-growth wood, and the fact that wide color variations have occurred in most cypress-growing localities (*4*), it is difficult to substantiate the validity of claims that color and timber sources are indexes of decay resistance for the heartwood of virgin baldcypress. The test results insofar as they go, are at least not

Table 2.--Resistance of outer heartwood of baldcypress trees to decay by 4 test fungi

Resistance class[1]	Test fungus			
	Poria monticola	Poria incrassata	Lenzites trabea	Lenzites striata
	Percent	Percent	Percent	Percent
Very resistant	0	4	15	4
Resistant	22	26	33	55
Moderately resistant	78	70	52	41
Nonresistant	0	0	0	0

[1] Resistance classes are relative to specific fungi, and are delineated by weight losses caused by the fungi in the test blocks as follows:

Very resistant----------0 to 10 percent.
Resistant----------11 to 24 percent.
Moderately resistant------25 to 44 percent.
Nonresistant----------45 or more percent.

Table 3.--Relation between color of outer heartwood and decay resistance of test blocks of baldcypress as indicated by the average weight loss for all 4 test fungi

Color class	Number of trees	Average weight loss		
		Minimum	Maximum	Mean
		Percent	Percent	Percent
Red (R)	1	.....	.....	8
Dark to medium brown (DB)	17	16	32	24
Light brown and tan (LB)	4	21	32	27
Light tan to faint brown (LT)	5	30	34	33

disagreement with the widespread opinion that "red cypress" is the most durable. It follows that the same opinion might be justified for some, but not all virgin "tidewater" cypress, since according to Mattoon (*4*) red cypress was formerly found only in some tidewater swamps. But whatever the situation, the decay resistance of "red cypress" is primarily of academic interest now, because the shortage of virgin timber places red heartwood in especially limited supply. Moreover, red cypress, as presently recognized in the trades, may include considerable amounts of wood of dark-brown shades as well as that having the distinctive reddish color.

In looking for correlations between decay resistance and other properties of the wood, a very slight trend—not statistically confirmed—indicated that decay resistance increases in the outer heartwood with increasing age of the tree. In practically all the samples tested, decay resistance tended to increase from the inner to the outer heartwood (table 1 and fig. 1). In figure 1, the relation is shown with the tree grouped in broad age classes. Such a radial trend seems to be common among other species having moderate to high decay resistance (*3,7,8,10,11*).

There was peckiness in the inner and middle heartwood of four trees from the Delta Experimental Forest in Mississippi. This condition, although manifesting a type of decay that occurred in the standing tree, was not associated with any inferiority of decay resistance; in fact, pecky test blocks were somewhat more resistant than blocks obtained from sound trees in the same area. The test results confirm previous reports, based on service-life observations, that pecky cypress is as decay resistant as nonpecky cypress (*4,14*).

In view of the slight tendency for decay resistance to be greater as the trees were older, and since resistance was also slightly correlated with the depth of color in the wood, it seems possible that the reputation of baldcypress for superior decay resistance may rest mainly on experience with wood from the uniformly large, old trees of virgin timber, and particularly that with the reddest color—such as reportedly occurred in tidewater swamps. Judging from the low correlation between decay resistance and age in the present trees, however, it would seem that the virgin timber of the past would have had to average considerably older than the old trees dealt with here in order to have had markedly greater decay resistance because of the age factor. Possibly substances associated with reddish color in the wood were the major determining factors of earlier superior resistance.

It would seem appropriate, therefore, to expect the heartwood of second-growth baldcypress to have an advantage in decay resistance mainly where decay hazard is relatively moderate, such as with conditions of exposure above ground. Generally the indicated resistance would not justify recommending extensive use of the untreated wood in ground contact. Moreover, the results of this test indicate that no practical distinction as regards decay resistance of present-day timbers seems warranted between baldcypress from different growing areas or between baldcypress and pondcypress.

It should be emphasized that, in addition to lesser decay resistance in the second-growth heartwood than in the virgin heartwood, the proportional and total amounts of heartwood are smaller. Today, one commonly finds baldcypress lumber with as much as a third of its volume comprised of sapwood. Thus, for uses where the decay resistance of the heartwood is wanted, the stock must be selected accordingly. The presence of sapwood does not, of course, reduce the physical advantages characteristic of baldcypress, such as good nail-holding ability; ease of working; good paint retention; good stiffness and bending strength; and good resistance to wear.

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Effect of Temperature and Humidity of Glue Room on Open Assembly Time

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Limited open assembly time is a major problem to makers of glue-lam structural members. This work shows that the maximum permissible time varies with conditions in the glue room. In these tests, casein was much more sensitive to the atmosphere than resorcinol.

ONE OF THE MAJOR DIFFICULTIES facing the laminator in gluing large structural members, is the limited assembly time to which he is restricted by virtue of the glues employed. In particular, the maximum permissible open assembly time is short, being of the magnitude of 10 to 30 minutes at room temperature (8). Exposure of glue-coated wood surfaces to the glue-room atmosphere occurs where warped boards prevent close contact of contiguous boards in the assembly stage. Appreciable gaps thus occur, particularly when two-inch laminating stock is used. Hence, some of the glue-coated surfaces may remain exposed to the atmosphere up to as long as the time required for assembling the member.

The exposed glue will develop an initial set, or pre-cure, due to loss of solvent (water) to the air and to the wood. Glue which has acquired an initial set before the boards are brought into close contact produces a weak bond or no bond at all, depending on the degree of pre-cure (8,9). Obviously, members with defective glue bonds are not fit for service (4,5).

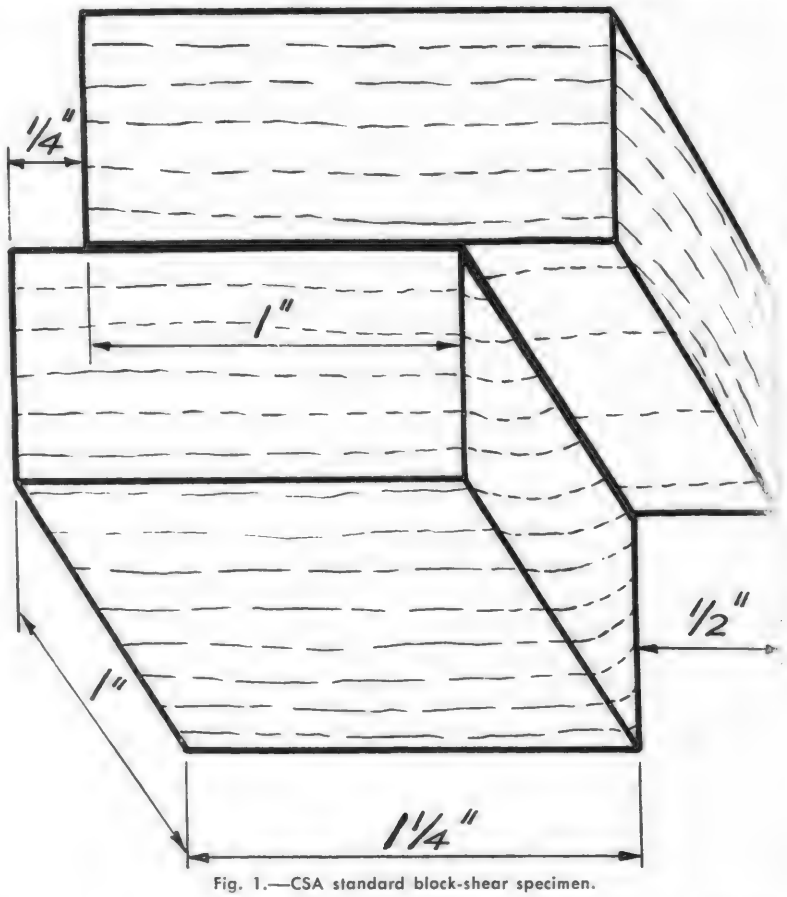

Fig. 1.—CSA standard block-shear specimen.

One way to decrease the chance of rejects occurring is by increasing the maximum permissible open assembly time. In general, this time decreases with increasing temperature. In the case of polymerizing adhesives such as resorcinol, the reduced permissible open assembly time at higher temperatures is caused partly by the ensuing higher rate of polymerization, and partly by the higher rate of solvent loss to the air. In this type of adhesive the solvent gives the adhesive its desired viscosity, and inhibits polymerization (7). Other adhesives set entirely due to loss of solvent from the glue. Casein belongs in this category, and the shortened effective open assembly time at higher temperatures is due only to the higher rate of solvent evaporation.

Temperature alone is not the governing factor in rate of evaporation. The rate of solvent evaporation is inversely proportional to the degree of saturation of the air. For a given absolute humidity, the degree of saturation of the air is inversely proportional to the temperature of the air (14). In consequence, the rate of solvent evaporation can be decreased either by increasing the absolute humidity by introducing water vapor into the air, or by decreasing the temperature of the air. An amplified reduction in rate of evaporation is obtained by cooling and humidifying the air simultaneously. Lowering the temperature has the additional effect of decreasing the rate of polymerization of polymerizing synthetic resin adhesives (

In order to produce a strong bond glue must be liquid enough to flow when pressure is applied to the assembly. Flowing is necessary because it permits the glue to penetrate into the wood, and to form a thin continuous glue line. Both are essential for the formation of strong glue bonds

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Objective and Scope

The purpose of this study was to determine to what extent relative humidity and temperature of the glue room atmosphere affect the maximum permissible open assembly time. In addition, it was hoped that the results might give an indication as to whether maximum permissible open assembly time can be lengthened substantially by controlled temperature and humidity. In that case, installation of air conditioning equipment in the glue room could be justified. The project was designed in such a manner that trends, rather than concrete results, would be indicated. No attempt was made to eliminate all variations in the wood itself.

Gluing conditions were chosen so as to reveal differences, if any, between different temperature and humidity levels and between a series of four open assembly times (Table 1). The time elapsing between glue mixing and spreading was kept to a minimum by the frequent replacement of mixes.

Table 1.—SCHEDULE OF TEMPERATURE AND RELATIVE HUMIDITY LEVELS OF THE GLUE ROOM ATMOSPHERE AND OPEN ASSEMBLY TIMES

Temperature F.	Relative Humidity Percent	Open Assembly Time (Minutes)			
Casein					
70	35 75	25	45	60	75
90	35 75	15	25	35	45
Resorcinol					
70	35 75	25	45	55	65
90	35 75	15	25	35	45

Materials and Methods

The Douglas-fir laminating stock was 1 inch by 6 inches nominal material, which had been kiln-dried and planed. Stock for gluing was carefully selected as to surface smoothness and absence of contaminating agents. Only straight-grained, defect-free material was selected. No attempt was made to segregate sapwood from heartwood, edge grain from flat grain, or high density wood from low density wood. The effect that these could have on the permissible open assembly time, and the resulting quality of the glue bond, are discussed.

Two adhesives were included in the project, casein and resorcinol. The casein used is described by the manufacturer as a self-bonding, water-resistant, cold-setting, fungus-and insect-resistant glue developed specifically for the fabrication industry. The working life of the mixed glue is 4 to 5 hours at room temperature. The resorcinol adhesive is described by its manufacturer as a boilproof resorcinol resin adhesive that sets at room temperature. The working life of the activated resin is 4 hours at 70°F. Maximum permissible open assembly times recommended by the manufacturer of the particular glues used were 15 minutes for the resorcinol, and 10 to 20 minutes for the casein glue, depending on the thickness of spread.

A uniform spread of 40 pounds per thousand square feet was used on each of the contacting surfaces resulting in a total rate of glue spread of 80 pounds per thousand square feet of single glue line. This spread is considered by the writers to be fairly representative of commercial practice, and within the limits recommended by the glue manufacturer.

Temperature and humidity control in the glue room was not positive enough to attain the exact values prescribed (Table 2).

Table 2.—ACTUAL ATMOSPHERIC CONDITIONS OF THE GLUE ROOM

Temperature °F.		Relative Humidity (Percent)	
Average	Range	Average	Range
71.0	70-72	74.3	72-77
70.3	68-73	38.5	34-43
91.9	90-93	76.4	74-78
92.0	89-94	35.2	30-41

As indicated above, the objective was merely to show trends, and accuracy in obtaining and maintaining exact atmospheric conditions was therefore not required.

The number of shear tests for determining glue bond quality was set at 24. This number is larger than generally used (10 to 15) for this purpose. In view of the expected variation in shear tests results, it was deemed necessary to use at least 20 shear tests for each gluing condition.

The quality of the casein glue bonds was determined by the block-shear test. The assemblies glued with resorcinol were tested by the block-shear as well as the delamination tests. Both were carried out in accordance with provisions of the Canadian Standards Association Specifications 0122(1953) except for the rate of loading in the shear test (5) which was at a rate of 0.035 inch per minute, instead of the 0.015 inch specified.

Test billets consisted of five 7-1/4 inch long laminates for casein, and six 12-1/2 inch long laminates for resorcinol. These yielded 24 block-shear specimens each (Fig. 1). Two delamination specimens, each consisting of a 2 inch wide cross-section of the glued assembly, were also obtained from each resorcinol billet. Both types of billets provided for adequate side and end trim.

WHAT THIS RESEARCH MEANS

Close control of the gluing process is mandatory in the production of glued-laminated timbers. The time taken to spread the glue, lay up the assembly, and apply pressure by means of clamps or otherwise, can be worked out satisfactorily with a smooth-working crew. However, variations of glue room temperature and relative humidity result from changes in the day to day weather. These are often uncontrolled in the plant, and may affect the success of gluing.

It was found that casein glue, after spreading, was more sensitive to a dry atmosphere at the warmer temperatures than was resorcinol. This was shown by lower shear strengths of test blocks. Maximum permissible open assembly times could be lengthened substantially if air conditioning equipment were installed in the glue room.

Experimental Procedure

Mixed glues were kept in a separate room at a temperature of 70°F. In order to eliminate the effect that different glue temperatures have on viscosity, and therefore on the permissible open assembly time (7), only a small quantity of mixed glue was brought into the glue room. The glue was used immediately and replenished as required. The periods during which the mixed batches of glue were used never exceeded half the effective pot life of the glues.

Laminating stock was kept in a separate room under relatively constant atmospheric conditions in order to eliminate further variables not under study (13). All stock used in gluing had a moisture content of 10.5 plus or minus 0.5 percent.

After the glue was spread, the laminates were placed on edge on a rack so as to be exposed on all sides to the prevailing glue room atmosphere. After the required open assembly time had elapsed, the laminates were brought together, and pressure was applied by means of clamps. A calibrated torque wrench was used to obtain a uniform pressure of 150 psi on each billet. All billets were kept under pressure for a period of 12 hours, at a temperature of 90°F. The clamps were then removed and the billets allowed to cure at room temperature for a period of at least 7 days. This curing period permits the glue bond to attain maximum strength (8).

Next the billets were cut in such a manner that all glue lines were represented. The blocks were then cut to produce the CSA standard block-shear specimen (Fig. 1). Care was taken to cut the specimens to the exact dimensions required, in order to obtain a glue-line area of precisely 1 square inch.

The block-shear specimens were tested on a Baldwin universal testing machine. The compression load at the time of failure was recorded to the nearest 5 pounds. Percent wood failure estimates were not taken because of the unreliable and subjective nature of this method of estimating glue—bond quality (2,11,15).

The delamination specimens were submitted to the standard vacuum-pressure cycle test. After the final drying period, the total extent of delamination on the two end-grain surfaces of each specimen was measured and expressed as a percentage of the total glue line length of the specimen.

Results

The arithmetic mean of the 24 failing loads was computed for each billet. These means and their standard deviations are presented in Table 3. Student's "t" test was used to establish the significance (at the 99 percent confidence level) of the difference between the average of the shortest open assembly time and the averages of subsequent open assembly times (Table 4) (10). To make comparisons more simple, the temperature levels of 70° and 90° F, as well as the relative humidity levels of 35 and 75 percent, are referred to in the remainder of this paper, instead of the actual values. Student's "t" test was again employed to establish the significance of the difference between average shear values of the same open assembly time (Table 4), and to indicate whether better results were obtained at high relative humidity levels than at low levels.

Discussion

From the means and their standard deviations (Table 4) it is apparent that variation in shear strength between specimens from the same billet was in most instances considerable. A brief discussion of the factors which are likely to produce these differences may be appropriate.

Glue bond strength depends mainly on specific adhesion which is defined as anchorage resulting from forces of adhesion acting between the molecules of the wood and those of the glue. The magnitude of these forces of adhesion depends on the polarity of the wood and the glue. The other type of adhesion in the gluing of wood is mechanical adhesion, which is defined as anchorage resulting from hardened tentacles of the adhesive extending into the wood. Mechanical adhesion is considered to be of minor consequence (7, 9). Adhesion between wood and the adhesive increases with the amount of excised (cut) cell walls at the surface of the wood. This is due to the fact that higher specific adhesion is obtained with excised cell walls than with unexcised cell walls (9).

Table 3.—AVERAGE SHEAR FAILING LOADS AND THEIR STANDARD DEVIATIONS BASED ON 24 SPECIMENS PER CELL

Resorcinol								
	90°F., 35% rel. hum.				90°F., 75% rel. hum.			
Open assembly time, minutes	15	25	35	45	15	25	35	45
Mean failing load, psi	1146	1149	1013	681	1082	934	966	1141
Standard deviation	328	438	381	344	339	304	356	381
	70°F., 35% rel. hum.				70°F., 75% rel. hum			
Open assembly time, mintes	25	45	55	65	25	45	55	65
Mean failing load, psi	889	828	532	507	986	941	1219	929
Standard deviation	334	334	288	274	220	348	400	338
Casein								
	90°F., 35% rel. hum.				90°F., 75% rel. hum			
Open assembly time, minutes	15	25	35	45	15	25	35	45
Mean failing load, psi	992	786	576	56	926	1121	890	1092
Standard deviation	390	457	483	118	288	273	488	286
	70°F., 35% rel. hum.				70°F., 75% rel .hun			
Open assembly time, minutes	25	45	60	75	25	45	60	75
Mean failing load, psi	969	479	161	74	1026	1079	715	490
Standard deviation	295	431	292	183	420	395	464	439

Wood Density: Wood density affects gluability in three ways. First, the denser the wood of a particular coniferous species, the lower will be its porosity. The pores absorb the glue, in particular the solvent fraction, as a result of capillary action. Consequently, glue spread on a dense wood surface stays wet (liquid) longer than glue spread on a less dense wood surface, thus permitting a longer open assembly time. Second, the higher the density of the wood, the higher is the percentage of excised cell walls at the wood surface, resulting in greater adhesion between glue and wood.

If conditions are such that the glue produces a bond stronger than the wood—as glues are designed to do—the shear test will break the specimen through the wood, rather than through the intersurface of glue and wood. In that case, the shear test does not indicate the glue bond strength but the strength of the wood. This concept introduces the third way in which wood density affects the glue bond quality, when the latter is measured by the shear failing load: specimens showing a high percentage of wood failure vary in shear strength in proportion to the density of the wood (2, 3, 9, 15).

In this project, the laminating stock was not segregated as to density because it was felt that a random selection of laminates in each billet, coupled with the relatively large number of test specimens, would give results from which conclusions could be drawn in spite of the variations. From the tests for significance of differences, it can be seen that this was justified.

Percent Summerwood: Summerwood is the denser fraction of the wood. The amount of summerwood that is exposed at the surface depends on the density of the wood, and the angle between annual rings and the wood surface. On flat-grain surfaces relatively large areas are either summerwood or springwood, depe g on which part of the annual ring at that particular part of the su c. Analogous with the consider ns under density of wood, the dense n- merwood permits longer open a n- bly times.

Slope of Grain: It was indi d above that only straight-grained ck was selected for the project. How r, slight local deviations always o r. The effect of grain not perfectly r- allel to the surface is that the ra- cheids are cut obliquely to their l g- tudinal axis. The resulting open gs, which constitute cell cavities, form ve- nues through which glue, in particular the solvent fraction, can migrate away from the wood surface due to capillary action. The greater the slope of grain, the more pronounced will be the i g- ration away from the surface. Where slope of grain is particularly large a considerable amount of glue will migrate into the wood. If the glue spread is relatively light, little or no glue may remain at the surface, causing a starved glue line (9). The degree of slope of grain, therefore, influences the drying rate of the glue.

Sapwood versus Heartwood: The sapwood in most species is more p r- meable than the heartwood because it lacks the extraneous materials found in the heartwood. In Douglas-fir the extraneous materials may partially plug the tracheid cavities, the bordered p s, and the resin ducts, thus reducing the rate and amount of glue penetrating into the wood. This lower permeability of heartwood is pronounced after l g- drying. Consequently, heartwood f- fords longer open assembly times

Extraneous materials in heartw d have an adverse effect in that they t d to reduce the specific adhesion fo s between unexcised cell walls and he adhesive. Therefore, if open assem y times are short, the sapwood will p duce stronger bonds than the h wood. With long open assembly ti on the other hand, heartwood prod s stronger bonds (3, 7, 9, 15).

Table 4.—COMPARISON OF AVERAGE SHEAR FAILING LOADS, RESORCINOL AND CASEIN, BASED ON 24 SPECIMENS PER CELL

Temperature, °F.	Open assembly time, minutes	Average failing load, psi Relative Humidity 35%	75%	Difference
90	15	1146	1082	— 64
	25	1149	934	— 215
	35	1013	966	— 47
	45	681*	1141	+ 460**
70	25	889	986	+ 97
	45	828	941	+ 113
	55	532*	1219	+ 687**
	65	507*	929	+ 422**

Casein

Temperatures, °F.	Open assembly time, minutes	Average failing load, psi Relative Humidity 35%	75%	Difference
90	15	992	926	— 66
	25	786	1121	+ 335**
	35	576*	890	+ 314**
	45	56*	1092	+1036**
70	25	969	1026	+ 57
	45	479*	1079	+ 600**
	60	161*	715	+ 554**
	75	74*	890	+ 816**

*Significantly different from the shortest open assembly time in each series of four open assembly times.
**Significantly different.
The confidence level for tests for significance of differences is 99 percent.

Table 5.—PERCENT DELAMINATION OF BILLETS GLUED WITH RESORCINOL UNDER DIFFERENT ATMOSPHERIC CONDITIONS

Temperature °F.	Open assembly time (minutes)	Percent delamination 35% relative humidity Block 1	Block 2	Average	75% relative humidity Block 1	Block 2	Average
90	15	12.9	12.5	12.7	6.5	2.5	4.5
	25	38.1	27.7	32.9	0.8	0.0	0.4
	35	79.8	66.6	73.2	2.1	0.0	1.1
	45	75.0	75.6	75.3	12.1	0.8	6.5
70	25	45.0	50.0	47.5	5.0	9.4	7.2
	45	100	77.8	88.9	23.7	17.7	20.7
	55	100	100	100	11.7	1.7	6.7
	65	100	100	100	48.5	24.8	36.7

Moisture Content of the Wood: The moisture content of the gluing stock was uniform enough (10.5 plus or minus 0.5 percent) that variations attributable to wood moisture content were minimized. The optimum range of wood moisture content for the glues involved is from 8 to 12 percent (1, 8, 13).

When determining the quality of the glue bond by means of the shear test, it must be kept in mind that this bond is no stronger than the weakest of the five links in it (3). These five links are:

1. The wood on one side of the glue line,
2. The bond between wood and glue,
3. The glue line itself,
4. The bond between wood and glue, on the other side of the glue line,
5. The wood on the other side of of the glue line.

All except link three have been considered. The strength of link three depends on four factors: (a) the cohesive forces of the molecules of the glue, as determined by its formulation; (b) the continuity of the glue line, which is governed by glue spread, porosity of the wood, permeability of the wood, viscosity of the glue at the time of pressure application, and amount of pressure applied; (c) the porosity of the glue line, which results from solvent and gases leaving the glue as it sets. The porosity is governed by glue formulation and glue line thickness; (d) the thickness of the glue line, which depends on a combination of spread, smoothness of wood surface, wood porosity and permeability, viscosity of the glue at the time of pressure application, and amount of pressure applied. The thicker the glue line, the lower will be its shear strength. This is due to the relatively greater porosity, and the higher shearing torque in thick glue lines (6).

In Table 4 it is clearly shown that, at the low relative humidity level, glue bond strength decreases significantly with increase in open assembly time. At the high relative humidity level no significant drop is indicated, for the same range of open assembly times. It also becomes immediately evident that casein is more sensitive to atmospheric conditions than resorcinol. This, of course, could be expected because casein sets primarily due to solvent loss, whereas resorcinol sets due to the combination of solvent loss and polymerization.

The delamination test results for resorcinol (Table 5) substantiate the shear test results. Much lower delamination occurred in all test specimens glued at the high relative humidity level than in comparable specimens glued under the low relative humidity condition.

With the resorcinol glue the unexpected situation occurs that, at 35 percent relative humidity level and 25 minutes open assembly time, a significantly (99 percent confidence level) weaker glue bond is obtained at the lower temperature level than at the high temperature level. The explanation for this may be that the peak of effectiveness of resorcinol does not occur until some time after activating the resin, that is after mixing the glue. The time at which this peak is reached decreases with increase in open assembly time and glue temperature (7, 12). However, this factor is contributary in nature only, and therefore can not be held solely responsible. Rather, a combination of unfavorable factors should be credited.

Differences between the effect of temperature, at the 75 percent relative humidity level, on glue bond strength were not found to be significant for the two open assembly times available for this comparison (25 and 45 minutes). It can be expected that, if comparable data beyond 45 minutes open assembly time were available, the lower temperature level would produce better results.

Finally, a comparison between the results obtained at the high drying condition (90° F, 35 percent relative humidity), and those obtained at the low drying condition (70° F, 75 percent relative humidity) is in order. This comparison is of particular importance, since in lowering the temperature of a body of air its relative humidity increases (14). From Table 4, it can be seen that, both for casein and resorcinol, a longer open assembly time is possible at low drying conditions than at high drying conditions. For resorcinol, the delamination test again supports the shear test results.

Conclusions

The purpose of the project was to determine what effect temperature and relative humidity of the glue-room atmosphere have on the maximum permissible open assembly time. The conclusions that can be drawn from the results of the project are:

1. For temperatures below 90° F, resorcinol is less sensitive to atmospheric conditions than casein.
2. At the same temperature, high relative humidities permit longer open assembly times than low relative humidities.
3. Lowering the temperature and increasing the relative humidity simultaneously results in a substantial increase in maximum allowable open assembly time.

An indication of how much the maximum permissible open assembly time could be increased by controlling temperature and relative humidity can

be gained by drawing a limit of acceptability at 900 psi shear failing load. For casein, the effective open assembly time is increased from 15 minutes at the high drying condition to 45 minutes at the low drying condition. This indicates that airconditioning could serve to substantially increase the maximum permissible open assembly time, in particular for casein adhesives.

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A CUTTING DEVICE FOR . . .

Laboratory-Scale Veneer Studies[1, 2]

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Research in veneer cutting on a full-scale basis is costly, time consuming, and difficult to control. Here is a small-scale cutting device for use with small sizes in the laboratory where temperature, moisture content, cutting variables, and other conditions can be more uniformly controlled.

Fig. 1.—Baldwin impact testing machine equipped with Izod specimen holder and 2 ft.-lb. hammer. (Baldwin-Lima-Hamilton Corporation)

Fig. 2.—Front view of modified impact testing machine. A. Knife-nosebar assembly; B. Pendulum with block holder, shown in position ready for cutting stroke; and C. Energy scale.

IN SPITE OF THE PROMINENT POSITION of veneer as a wood product, relatively little investigation has been directed toward a sound understanding of the actual processes involved in its production. If the fundamental relationships involved in veneer cutting were more thoroughly understood, a substantial improvement in the quality and yield of commercially produced veneer might be realized. Better understanding of these relationships could well pave the way toward development of cutting techniques adapted to species or types of wood previously considered as being unsuitable for conversion to veneer.

The very nature and size of a commercial veneering operation make research on a full-scale basis unwieldy and expensive. Perhaps for these reasons the literature in this field is somewhat limited. A few full-scale investigations have been carried out, such as those reported by Fleischer (2)[3] and Wangaard and Saraos (6), but their studies were limited to only a few of the numerous variables of both wood and machinery that may influence the cutting of veneer.

It was felt that research on a small scale might be successful in revealing the basic relationships that are ap[illegible]

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[1] Presented at the Northeast Section Meeting in Worcester, Mass., Oct. 30, 1959.

[2] This research is part of a comprehensive study being conducted at the Yale School of Forestry in cooperation with the Office of Naval Research, Department of the Navy, under Contract Nonr 609 (13), Project NR 330–001, Properties of Tropical Woods.

[3] Numbers in parentheses refer to Literature Cited.

Fig. 3.—Rear view of modified impact testing machine. A. Knife-nosebar assembly; B. Pendulum with block holder, shown in final position after completion of cut; and C. Pendulum arrest plate.

Fig. 4.—Front view of knife-nosebar assembly; A. Assembly frame; B. Knife; C. Knife holder; and D. Nosebar.

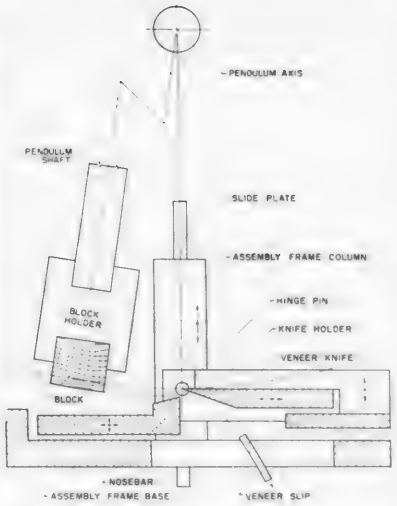

Fig. 5.—Diagrammatic section view of the principal cutting parts of the experimental apparatus. Arrows indicate direction of adjustments. Dashed lines show the path of the veneer block during the cutting stroke.

able in producing veneer by any of the knife-cutting processes. This approach has been successfully demonstrated by McMillin, who studied, by means of a converted milling machine, the relationship of certain strength properties of wood to nosebar pressure in veneer production (5).

The present paper describes a technique for small-scale veneer cutting based on a modification of a standard Izod—Charpy impact testing machine. This method uses the principle of the impact test to the extent that power is supplied by the gravitational swing of a weighted pendulum arm and that energy consumption is measured by retardation of the pendulum. In the veneer-cutting apparatus, a rigidly mounted knife intercepts the path of a small wood block attached to the swinging pendulum, removing a layer of veneer as the block swings past the knife. Cutting of the veneer impedes the swing of the pendulum by a measurable amount, thus indicating the energy consumed in the cutting process.

The impact tester was modified to include a knife-nosebar assembly which is fully adjustable for such variables as vertical and horizontal nosebar opening, knife angle, and thickness of veneer. A small specimen is used which can be varied conveniently with regard to species, density, grain orientation, and preconditioning treatment.

Several other advantages are realized in the use of small-scale veneer cutting apparatus. The convenience of working with small sizes can readily be appreciated. Specimens are more closely matched from one test to the next. Temperature, moisture content, and other conditioning can be controlled more uniformly within a single specimen and more closely among different tests. Also, variations in the design of the knife and nosebar can be readily introduced.

Such a method, however, is not without some limitations which must be recognized. For example, the speed of cutting is different from that in an actual operation; and McMillin has suggested that checking may be increased with increased speed of cutting. In addition, small specimens do not permit study of the wide cyclic variations in veneer thickness that result from low knife angles. The design of the cutting apparatus requires a fixed pendulum length and thereby prohibits investigation of the effects of varying the cutting radius. "Miniature" veneer specimens also present problems in quality evaluation.

Even though every laboratory variable may not be directly parallel with its counterpart in full-scale cutting, there is evidence that enough relationship does exist to indicate that investigation at the laboratory level will reveal important aspects of the cutting process itself. This information, when properly interpreted, could greatly advance the understanding and performance of veneering techniques in commercial production.

The apparatus described is still in a development stage and, although some exploratory cutting tests have been made, the completed work has been concerned with an investigation of the mechanical performance of the

WHAT THIS RESEARCH MEANS

Fundamental knowledge is generally limited in the field of veneer cutting. Since research on a full-scale basis is difficult, a suitable laboratory method of investigating veneer cutting should be invaluable to the industry.

This paper offers an approach to convenient study of both machine and wood variables that influence veneer quality. It is very probable that such a method will have application in improving the quality of veneer produced from presently used species, and it will also provide a ready means of investigating new species and techniques.

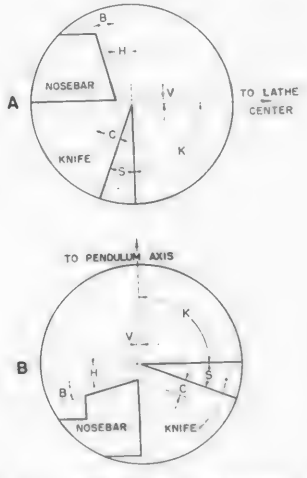

Fig. 6.—Diagrammatic comparison of knife-nosebar orientation in (A) a typical commercial veneer lathe and (B) the experimental apparatus. The following terminology is used: H = Horizontal nosebar opening; V = Vertical nosebar opening; C = Nosebar clearance; K = Knife angle; S = Knife sharpness angle; B = Nosebar bevel.

equipment rather than with the ultimate objective of studying the relationships between machine conditions and veneer quality. Therefore, the purpose of this paper is primarily to explain the nature of the experimental apparatus and the principles involved in its operation. Although the results of a limited series of preliminary cutting experiments are reported in a later section, these findings are included only to illustrate generally the possibilities of the apparatus. No attempt has been made to draw conclusions from these initial data.

Description of Apparatus

Figure 1 shows the Baldwin Impact Testing Machine (Bell Telephone Laboratories Type) fitted with specimen holder and striking hammer for the standard Izod impact test. Modification of this machine for veneer cutting involved two general changes. As shown in Figures 2 and 3, a knife—nosebar assembly (A) was attached to the machine base, replacing the Izod specimen holder. The Izod hammer was replaced by a weighted pendulum (B) with a built-in block holder.

As illustrated in Figure 2, the pendulum is released from its highest position so that it swings past the knife-nosebar assembly and cuts a slip of veneer from the face of the block. The nominal thickness of the veneer depends upon the height adjustment of the knife-nosebar assembly. In cutting the veneer from the specimen block, the momentum of the pendulum is reduced, thus impeding the pendulum from rising to its original height on the opposite side of the stroke. The difference between the initial height of the pendulum and the height at the end of the stroke gives a measure of the energy lost in the cutting process. The magnitude of this energy consumption is determined by means of a scale (C, Figure 2) graduated over the entire capacity range of the pendulum. After completion of the cutting stroke, a small mechanism on the pendulum engages with the teeth of the pendulum arrest plate (C, Figure 3). This stops the return motion of the pendulum and thus prevents the block from scuffing back across the knife edge.

The principal parts of the cutting mechanism are shown in Figure 4. The knife-nosebar assembly frame (A) is essentially a flat bed plate with upright columns on either side. Channels in the outside faces of the columns slide vertically on the edges of steel plates fixed to the machine posts. The height of the assembly frame is adjusted by set and lock screws threaded into the machine base. The veneer knife (B) is held rigidly in the knife holder (C) which lies horizontally between the assembly frame columns. The knife holder is attached to the columns by two pins which are so located as to allow the knife to rotate about an axis passing through the knife edge. The hinge-pin center line is parallel to the axis of rotation of the pendulum arm and in the same vertical plane. Set screws at the rear of the knife holder provide for horizontal positioning of the knife edge exactly on the hinge-pin center line. Screws at the rear of the knife holder permit adjustment of the knife angle. The nosebar (D) is also attached to the assembly frame. Adjustment screws enable precise settings of vertical and horizontal nosebar openings.

Figure 5 presents a diagrammatic section view of the principal parts described above. Directions of adjustment are indicated as well as the path of the block during the cutting stroke.

The pendulum is provided with knurled jaws for holding the specimen, and with sufficient weight to satisfy anticipated energy requirements. In addition, its design provides for elimination of vibrational reaction forces. This is accomplished by a distribution of weight such that the center of percussion of the pendulum is located within the block.

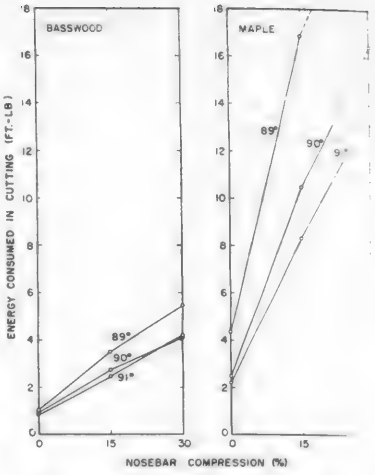

Fig. 7.—Relationship of energy consu in cutting 0.0606-inch veneer to nos compression at knife angles of 89, 90, 91°.

The pendulum arrest system cons of a ratchet plate mounted on main machine casting and a pawl u attached to the pendulum shaft. T pawl unit has a lightly tensio strip pawl which rides freely over t ratchet plate during its upward n tion, but which engages the ratc teeth as the return swing begins. Th light strip pawl causes the pawl u to rotate and to engage a heavy paw bar which stops the pendulum.

Terminology

The principal machine parts in volved in the cutting process are th knife and nosebar. Conditions in fluencing the cutting process can b described by the position and nature of these parts in relation to each other and in relation to the lathe cen ter. (Although reference to the lath center presumes the rotary process, all other basic relationships are equally applicable to other methods of knif cut veneer production.) Figure 6A shows diagrammatically the relation ship of the knife and nosebar

Table 1.--RELATIONSHIP OF ENERGY CONSUMED AND THICKNESS TO NOSEBAR COMPRESSION FOR 0.060-INCH VENEER CUT AT THREE KNIFE ANGLES. (EACH VALUE IS AVERAGE OF SEVEN SPECIMENS FROM SAME BLOCK).

Species	Nosebar compression (inches)	Knife Angle, Degrees					
		89		90		91	
		Energy (ft.-lb.)	Thickness Ratio (a/Ta)[1]	Energy (ft.-lb.)	Thickness Ratio (a/Ta)[1]	Energy (ft.-lb.)	Thickness Ratio (a/Ta)[1]
[illegible]	0	1.04	1.045	0.96	1.032	0.86	1.027
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	---	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[1] Thickness ratio = (Actual thickness/Nominal thickness).

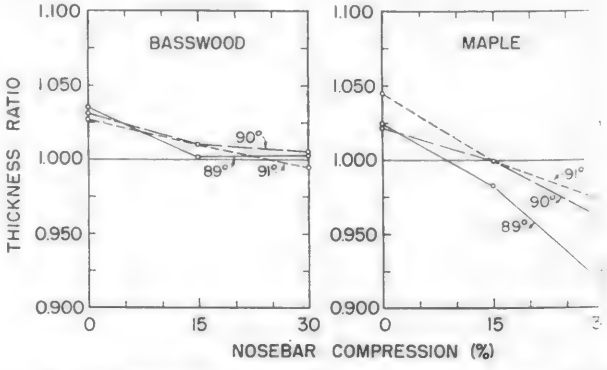

Fig. 8.—Relationship of veneer thickness to nosebar compression knife angles of 89, 90, 91° in cutting veneer of nominal 0.060-inc thickness.

oriented in a commercial lathe. The relative shape and orientation of the analogous parts contained in the experimental equipment are shown in Figure 6B.

The terminology used in this paper corresponds to the designations of Figure 6 as follows:

H = Horizontal nosebar opening
V = Vertical nosebar opening
C = Nosebar clearance
K = Knife angle (sometimes called "clearance angle")
S = Knife sharpness angle
B = Nosebar bevel (sometimes called "nosebar angle")

It must be recognized that other terminology is in use for the relationships presented above and that measurements are sometimes made to other reference surfaces of the machine parts. However, the above nomenclature is generally consistent with most descriptions given in American literature.

It will be noted that although the orientation of relative parts of the experimental apparatus is rotated by 90° from that of a commercial lathe, the terminology used in commercial practice is applied to the analogous experimental parts. For example, the horizontal nosebar opening (H) of the experimental equipment is really a vertically oriented dimension, but is analogous to the horizontally measured distance in the usual rotary knife-nosebar assembly.

In standard practice, the veneer knife is oriented with the beveled surface tangent to an arc about the spindle center, so that the freshly cut surface of the veneer bolt passes over this beveled face of the knife and the peeled veneer comes out along the back of the knife. In the experimental assembly, the veneer knife is oriented with its "back" tangential to the arc of the cutting radius and the severed slip of veneer passes along the beveled "face". The beveled face of the standard knife is usually ground with a slight concavity whereas both surfaces which form the cutting edge of the experimental knife are machined flat. Resharpening is accomplished by surface grinding the entire "back" of the experimental knife. The only consequence of this deviation from standard design lies in the omission of a concave surface on the sharpened face, but it is felt that a flat surface is desirable from the standpoint of maintaining uniformity.

The nominal thickness of veneer (T_n) is the distance by which the knife is advanced toward the lathe center during one revolution of the lathe spindle. Similarly the distance by which the experimental knife is advanced toward the pendulum axis between successive cuts is considered as the nominal thickness (T_n).

The amount by which the nosebar compresses the wood as it is being cut may be expressed as a percentage of the nominal thickness and may be computed as:

$$NBC = 100\ (T_n - C)\ /T_n$$

Where: NBC = Nosebar compression, percent
T_n = Nominal veneer thickness, inches
C = Nosebar clearance, inches

The nosebar clearance is the opening between the knife and nosebar through which the veneer must pass, and is determined by the equation:

$$C = (H + V\tan\alpha)\cos\alpha$$ [1]

Where H = Horizontal nosebar opening, inches
V = Vertical nosebar opening, inches
α = (Knife angle, K) — (90° — Knife sharpness angle, S)

The upper surface (or face) of the knife is initially adjusted perpendicular to a line from the pendulum axis to the knife edge. This corresponds to a knife angle of 90°. Angles of more or less than 90° are set by adjustment screws. A vernier scale enables setting the knife angle to an accuracy of 2.5 minutes of arc.

Vertical and horizontal nosebar openings are calculated to give the appropriate C value for any desired nosebar compression. The vertical opening is measured with the aid of a jig which temporarily forms a continuation of the vertical surface of the nosebar. A thickness gage is used to measure the distance between the jig surface (or projected nosebar surface) and the knife edge to the nearest 0.001 inch. The horizontal nosebar opening is determined by means of a jig equipped with a dial indicator mounted in a vertical position to measure the difference between the height of the nosebar and the knife edge.

The distance the knife-nosebar assembly is raised between successive cuts (that is, the nominal thickness) is measured to the nearest 0.001 inch by means of a dial indicator permanently mounted on one of the slide plates. The reference base is a block attached to the assembly frame as shown in Figure 4.

The total energy capacity of the pendulum is its effective weight multiplied by the vertical height of drop. The effective weight is the weight of the pendulum measured at its center of percussion when the pendulum is suspended horizontally. The height of drop is the vertical distance from the center of percussion of the pendulum at its initial position (that is, ready for release) to the knife edge. The energy scale, from zero to maximum height, is divided into 200 units, each of which represents 0.5 percent of the total energy capacity of the machine. Dial readings, which range from 0 percent capacity at the top of the scale to 100 percent capacity at the lowest point, are converted into energy consumption by the equation:

$$E = DF$$

Where: E = Energy consumed in cutting, ft.-lb.
D = Dial reading, expressed as percent of total capacity
F (a conversion factor) = (height of drop, ft.) x (effective weight, lb.)[5]

Cutting Technique

Specimen blocks are machined to size in the saturated or "green" condition, and are stored in water until ready for use. As yet, cutting has been done only on cold (room temperature) soaked material.

The "veneer block" from which slips of veneer are cut is machined to 1- by 1 by 1¼ inch. The 1-inch square surface is parallel to the top surface of the knife during the cut, thus giving a 1- by 1-inch veneer piece. The block is oriented with the wood fibers parallel to the knife edge. (In cutting to simulate a peeling technique, the block is machined so that the 1- by 1-inch face is a tangential surface.)

When all initial settings of the machine are complete, the knife-nosebar assembly is adjusted to its lowest position. The block is then clamped in the jaws of the block holder. Test swings are made, raising the knife after each swing, until a fresh surface of the block is exposed. The knife is then raised by an amount equal to the nominal thickness. The pendulum is then allowed to swing from its initial position, and the first slip of veneer

[1] The equation $C = (H + V\tan\alpha)\cos\alpha$ is accurate where the ratio $V/H \leq \tan\alpha$. For $V/H > \tan\alpha$, the equation $C' = \sqrt{V^2 + H^2}$ expresses the opening between the knife and nosebar through which the veneer must pass. However, in practice the ratio V/H rarely exceeds tan α, so that C rather than C′ is usually applicable.

[5] In the preliminary cutting work the height of drop was 2.18 ft. and the effective weight was 8 lb., giving a conversion factor of F = (2.18 ft.) (8 lb.) = 17.44 ft.-lbs.

is cut from the block. The knife is then lowered slightly to clear the block on its return stroke. The pendulum is disengaged from the pendulum arrest plate and returned to its starting point. The veneer specimen is labeled with an identification number, the energy value is recorded, and the knife is advanced for the next cut. This sequence is repeated until the exposed portion of the block has been cut.

Release of the pendulum for successive cuts is done at equal time intervals. Between cuts, the block is kept covered with a wet cloth to prevent drying.

In the initial cutting tests, it was noted that the block would often break ahead of the knife as the knife approached the end of the cut. The fracture was apparently due to stresses resulting from the compression by the nosebar. In the cutting technique that has been adopted this difficulty is overcome by cutting a small bevel along the rear edge of the block, thus gradually relieving the compression at the very end of the cut. To insure uniformity in successive cuts, a jig is used to guide the knife used for cutting this bevel. This operation is performed before each cut of veneer.

In the cutting of saturated blocks, the veneer slips are stored in water until saturated thickness measurements are made. All specimens are then pressed momentarily between blotters to remove excess water. They are then dried slowly in a temperature-humidity controlled atmosphere between small stickers (1/32 by 3/32 inch) with just enough pressure to keep them flat. After conditioning, the veneer slips are ready for measurement of dry thickness, evaluation of surface smoothness, or for machining in preparation for evaluation of checking or other cutting damage.

Preliminary Results

Experimental veneer cutting with this machine up to the present time has been limited to trial tests of its capabilities and to providing material for investigation of methods of evaluation. Two species, sugar maple and basswood, were water saturated and cut at room temperatures using 3 nosebar compression levels (0, 15, and 30 percent) with each of 3 knife angles (89, 90, and 91°). A nominal thickness of 1/16 inch (actually 0.060 inch) was used for all work.

Figure 7 shows average values of energy consumed in cutting each species at each combination of variables tested. For both species, the energy loss increased with increasing nosebar compression. Energy loss increased also as the knife angle was decreased. Most striking is the comparison of the two species. Maple (sp. gr. = 0.64, oven-dry vol.) has a much greater energy requirement in cutting than does basswood (sp. gr. = 0.38, oven-dry vol.). At the 30 percent nosebar compression and 89° knife angle condition, the resistance to cutting of the maple exceeded the capacity of the machine.

Figure 8 shows thickness ratio (ratio of actual to nominal thickness, T_a/T_n) for both species at all test conditions. Decreasing values with increasing nosebar compression result in part from the compression-set condition associated with extreme nosebar compression, but compression resulting from the bearing of the knife on the block is also apparently involved as shown by the knife angle effect.

The results described above are summarized in Table 1. Each value represents the average of 7 veneer slips cut from a single block.

Veneer specimens for determination of depth of checking were prepared by a method similar to that described by Limbach (4). Visual ratings of the veneer cut from both species showed a marked reduction of knife check depth at 15 percent nosebar compression as compared with 0 percent. Little if any improvement was observed at 30 percent compression; in fact, quality was visibly lowered at the highest nosebar compression due to crushing of the veneer at the closed face. Checking seemed to increase slightly in severity from the 91° knife angle to the 89° knife angle in both species.

Surface smoothness, as rated visually, showed a trend of decreasing roughness from the 91° knife angle to the 89° knife angle. Surface smoothness was equally good at both the 15 percent and 30 percent nosebar compression levels, but veneer cut at 0 percent showed striking roughness, apparently associated with knife checking.

Quantitative evaluation of small veneer specimens is being investigated. It is anticipated that measurements of knife check depth can be taken using a method similar to the bevel-cut method reported by Batey (1). Quantitative rating of surface smoothness will be attempted through the use of low-angle lighting. The importance of veneer strength in tension perpendicular to the grain in quality evaluation has been demonstrated by Kivimaa (3) and Wangaard and Saraos (6). It is hoped that a suitable method of testing small veneer specimens can be perfected through some adaptation of paper tensile-testing equipment.

Future Potentials of the Apparatus

Investigation of several variables that may influence veneer cutting is planned in the immediate future. In addition to knife angle and nosebar clearance, these plans include cutting a wide variety of woods at different temperatures following different moisture–conditioning treatments. It is anticipated that this can be accomplished by means of a small portable chamber into which the specimen block can be swung between cuts to maintain a specified condition. Variations in grain orientation to simulate quarter slicing, stay-log cutting, etc. as well as non-conventional grain orientation, such as that associated with knots, are also anticipated.

Other factors are under consideration for future study. These include variations of the knife involving steels of varying composition and hardness, different grinding and honing techniques, changes in sharpness angle and knife profile, etc. Non-conventional treatment of the wood itself is under consideration, such as pretreatment with chemicals or lubricants, to determine the effects of such treatment on veneer quality or ease of cutting.

Finally, it is possible that the general principle of the veneer-cutting apparatus might be applied to machining studies quite apart from veneer-knife action. For example, substitution of a planer-knife segment or chipper knife in place of the veneer knife might lead to interesting results.

Although the status of this new phase of veneer-cutting research is still in the developmental stage, preliminary work has been encouraging. It is hoped that further development will lead the way to solution of some of the complex relationships involved in veneer cutting, to the end that improvement may be effected both in commercial practice and in our general understanding of wood properties.

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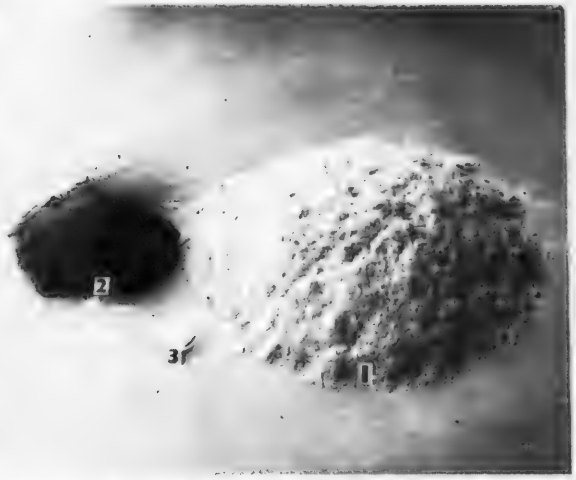
Bonding Particle Boards *with* Bark Extracts[1,2]

Components of 1-foot square board listed in Table 1: 1) fiberized sawdust; 2) bark powder; 3) paraformaldehyde.



Components of 1-foot square board listed in Table 9: 1) Paraformaldehyde; 2) disintegrated planer shavings; 3) wax emulsion; 4) concentrated bark extract.

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Additional work is needed but it appears probable that satisfactory particle boards could be produced with a resin formulation consisting of bark extract and formaldehyde, with *Pinus Radiata* bark as a source of extract.

IN THE PAST DECADE THERE has been a marked trend towards the manufacture of building boards in which wood fibers, flakes or particles are bonded with a thermosetting resin. The problems of producing such boards are intimately associated with the available raw material and required quality of the product. To achieve the desired board, many factors need to be considered, not the least of which concerns the use of a bonding agent.

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Bark Powder as Bonding Agent Component

Comments: The possibility of using bark powder and formaldehyde as a means of replacing synthetic resin bonding agents for boards is an attractive one, especially in the case of particle boards where an appreciable proportion of the manufacturing cost is derived from the cost of the resin (7).[2]

Already the feasibility of using formaldehyde and various barks, including *Pinus radiata* bark, to bond boards has been demonstrated (2, 4, 5, 6). Subsequently others (19) have used Sal bark, areca-nut husk or spent tea leaves as the aldehyde reacting component, and an allied approach where a mechanically separated bark fraction and formaldehyde are reacted to form a substitute for phenol-aldehyde resins as used for plywood, has been described (20).

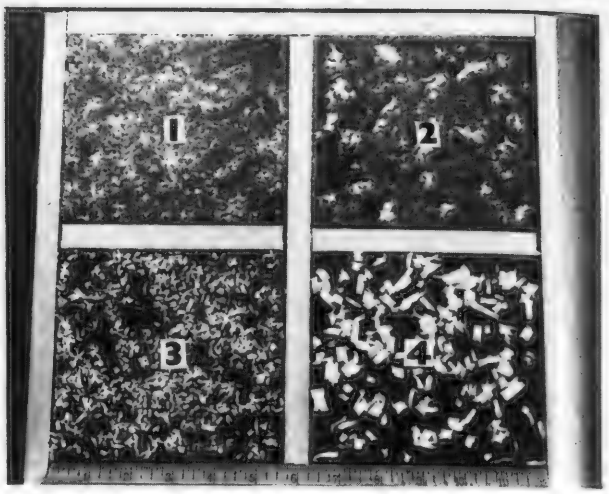
No extensive attempt has been made to repeat the work on *P. radiata* bark referred to above, but exploratory preparation of boards along similar lines confirmed that there were limitations to what could be produced in this way.

When such boards are pressed, it is considered that the tannin-like constituents of bark react with formaldehyde to form, within the board, a thermosetting resin capable of substituting for synthetic resin. If the bark-derived resin is to be effective as a bonding agent, it appears that when a board is pressed, there must be enough moisture and pressure to allow reactive components of the bark to be squeezed out before they combine with formaldehyde. Thus, it is necessary to apply substantial pressures which leads to

[1] A contributed paper received August 1959.

[2] Numbers in parentheses refer to Literature Cited at the end of the report.

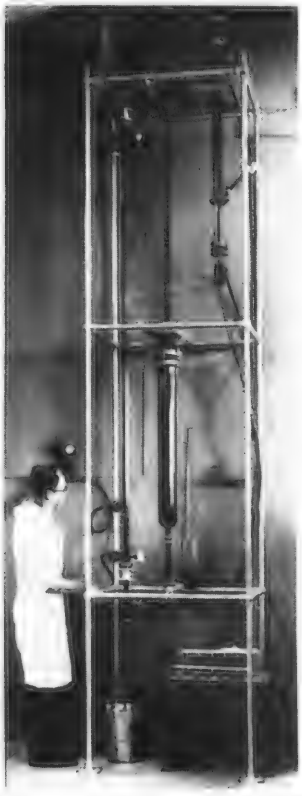
Electrically heated Archer press containing pressed board between stainless steel caul plates. Note pressed board in foreground.



Types of wood furnish: 1) fiberized sawdust; 2) dry pul[p] fibers; 3) selected sawdust; 4) disintegrated planer shavin

high density boards of limited application. Even if this is acceptable, smooth-two-sides boards of this type are inclined to split during pressure release.

Results achieved: Some success was achieved in making smooth-one-side boards with a surface appearance better than observed during the exploratory experiments referred to above, by working towards a wood fiber type of board. Table 1 indicates the results obtained.



Evaporator and multi-jet water pump used to concentrate bark extracts.

WHAT THIS RESEARCH MEANS

The potential value of bark as a raw material depends to some extent on its origin. Thus, whereas one bark may be a traditional source of tannin for converting hides to leather, it may be necessary to find a different use for the bark of another tree. There have been many searches of such a kind, of which a relatively small number have shown enough promise to be developed further, and of these only some have moved ahead to reach the point of commercial utilization. Quite often such a new development is conceived on the basis of what is known of the work of others.

This paper describes the more promising results obtained from an examination of the potential value of *Pinus radiata* bark as a raw material for the major component of a bonding agent for hot-pressed boards. Experiments show that it is technically feasible to use an extract of this bark in forming resin bonded wood particle boards without the addition of comparatively expensive synthetic resins. Only further work and the test of time will establish whether a development such as this has a commercial future that would contribute to the more satisfactory utilization of bark.

It was noted that boards 1 through 4, which had been prepared from furnish stored for 0, 1, 5, and 8 days respectively, showed a progressive drop in modulus of rupture and rise in water absorption, which is especially marked for boards 3 and 4. Therefore, bulk lots of furnish were not kept for over a day before pressing.

The pressing cycle was chosen somewhat arbitrarily with an initial pressure of 1000 psi. designed to consolidate the mat rapidly and to squeeze out bark extract before its reaction with formaldehyde. A subsequent lower pressure and breathing permitted reduction of the steam pressure generated within the board.

The bark-to-paraformaldehyde ratio was chosen on the basis of previous work (6).

A moisture content for the board furnish in the 45 to 55 percent range gave boards of the most satisfactory appearance. At a higher moisture content, bark extract was squeezed out from the board, leading to deposits of thermoset resin on caulplates, wire screen and press. At a lower moisture content, there was insufficient flow of extract to give a well bonded surface of even appearance.

The effect of pressing at 250°, 280° and 320° F. was examined, using furnishes with four different moisture contents within the range 40 to 60 percent on an oven-dry basis. Moisture content at test, which influences the physical properties (23), was more dependent on press temperature than on moisture content before pressing. Although it was not possible to discern any significant difference in modulus of rupture or water absorption, boards pressed at 320° F. were poorly bonded on the wire side.

Data given in Table 1 for boards 5 to 8 and 10 to 13 inclusive, show that with the use of finer screens there is an apparent trend towards higher moduli of rupture without there being any marked difference in water absorption, but because board densities were not determined there is some uncertainty about this observation. Lowering the bark content from 33 to 25 percent produced boards with modu

TABLE 1: BARK POWDER AS BONDING COMPONENT FOR HOT-PRESSED BOARDS (CALIPER 0.170-0.200 IN.)

Board No.	Bark Content (%)	Screen size mesh/inch	% Moisture at test (total wt.basis)	Mod. of rupture (p.s.i.)	Board wt. (lb./ 1000 o.d.sq.ft.)	Water Absorption (%/24 hr.)	Wood Furnish
1	33	12	12.0	3650	835	21.1	A
2	33	12	11.1	3520	815	23.1	A
3	33	12	9.6	2700	825	49.5	A
4	33	12	10.7	1290	795	73.7	A
5	33	36	13.9	2855	845	23.5	B
6	33	20	13.6	2755	845	26.0	B
7	33	12	12.6	2590	800	28.4	B
8	33	10	9.5	2340	830	31.8	B
9	33	20	12.7	5170	840	26.4	C
10	25	36	11.1	2580	800	39.6	B
11	25	20	13.7	2600	800	34.3	B
12	25	12	13.0	2410	765	40.6	B
13	25	10	12.0	2210	765	41.8	B
14	25	20	11.6	4800	770	36.4	C
15-16	25	12	13.6	2585	855	17.8	B

Notes: 1. Furnish A and B were different lots of fiberized sawdust. Furnish C was dry fibre.

2. Pressing conditions for all boards except 9 and 14. Press temperature 280°F., initial squeeze of 1000 p.s.i. for 10 sec., zero pressure for 20 sec., 250 p.s.i. for 10 sec., zero pressure for 20 sec. and thereafter 250 p.s.i. with zero pressure for 20 sec. once in 1.5 min. up to an elapsed pressing time of 8 min. Time to initial maximum pressure was 30 seconds.

3. Pressing conditions for boards 9 and 14: Press temperature 260°F. initial squeeze of 1000 p.s.i. for 90 sec., zero pressure for 20 sec., then as above using 300 p.s.i. instead of 250 p.s.i. Time to initial maximum pressure was 30 seconds.

of rupture and water absorptions approximately 10 percent lower and 40 percent higher, respectively.

For convenience, all boards detailed in Table 1, with the exception of 9 and 14, were produced using a selected screen fraction of sawdust that had been partially fiberized. Boards 9 and 14 were prepared using pulp produced by dry pulping *P. radiata* chips that had been pre-steamed. The physical properties, especially modulus of rupture, of these boards were more typical of wood fiber board and emphasize the importance to board strength of the quality of the wood derived component of the board. It is noted in this same connection that the apparent discrepancy in modulus of rupture between boards 1 and 7 is believed to stem from the use of different lots of fiberized sawdust, as indicated.

Apart from boards 15 and 16 the water absorptions recorded in Table 1 are undesirably high, particularly in the cases of boards containing 25 percent bark. The addition of 1.0 percent of paraffin wax to the board furnish lowered the water absorption to an acceptable level without detrimental effect as indicated by the data for boards 15 and 16.

Bark Extract as Bonding Agent Component

Comments: A survey of bark literature, an index to which has been compiled recently (15,16), failed to reveal any instance where bark extract-aldehyde resin had been used in place of synthetic resin to bond building boards.

The use of bark extract-aldehyde resins as adhesives for wood or veneer has been reported by Dalton (8), who later extended his work (9) to include experiments with a mixture of paraformaldehyde and sulphited tannin extracts of *P. radiata* bark.

Other work, on western hemlock bark (21,22), showed that solubility in the cold and yield of extract were both increased by extracting with dilute alkali instead of water, but no comment was made concerning the utilization of these alkaline bark extracts by reaction with aldehyde. Recently a patent (11) was granted for the preparation of sodium salts of bark extracts, especially from western hemlock using aqueous ammonia as extractant. No claim is made regarding the usefulness of any bark extract-aldehyde type of resin, but reference is made to the fact that the bark extract described will react with polymethylol phenols to form phenol-formaldehyde resins. Successful formulation of thermosetting adhesives of the exterior plywood type made from a sodium salt of western hemlock bark extract and polymethylol phenol as the major component has been described separately (12). In the same publication, references are given to other studies made on the use of bark extracts in plywood adhesives. Further recent experiments in preparing plywood and wood laminates with an adhesive in which the sole phenolic component was *P. radiata* tannin, obtained by cold water extraction of finely ground bark, have now been reported (3).

In this present work particular attention has been given to the hot

TABLE 2: SCREEN ANALYSES

	Screen Fractions (% by Weight)									
Mesh number U.S.S.140:1943	+5	+10	+18	+36	+60	+85	+100	+150	+200	-200
Coarse bark (Hammermill)	2.0	23.7	30.6	16.4	9.2	4.9	0.4	2.3	1.3	9.2
Fine bark (Bauer)	-	-	6.0	14.0	18.6	13.2	2.0	5.2	2.2	38.8

TABLE 3: BARK EXTRACTION RATE AT 60°C.

Extraction Time (min.)	% Solids In Liquors	
	2.5% Carbonate Extract	Aqueous Extract
5	5.5	3.4
10	5.5	3.3
15	5.5	3.4
25	5.6	3.4

TABLE 4: SOD. CARBONATE EXTRACT AS A BONDING COMPONENT FOR FIBREBOARD

Pressing time: 8 min. Paraformaldehyde: 6.0% of O.D. wt. of extract.
Press temp.: 300°F. Caliper: 0.160–0.173 in. Board wt.: 880 lb./1000 sq.ft.
ODW = Oven-dried weight.

Extr. Solids, % O.D. Wood	Moist. Content To Press, %ODW	Mod. of Rupture (p.s.i.)	Water Abs. (% 24 hr.)
2	39.7	2610	38.4
4	31.3	3160	32.5
6	45.6	5620	25.0
8	50.0	4865	26.8

alkaline extraction of *P. radiata* bark to obtain in substantial yield a resin ingredient for bonding building boards. Already a survey of the tannin content of bark of plantation-grown *P. radiata* had been carried out (10,13) using the method of Humphreys (14) and experiences related to extracting this bark had been outlined by Martin (17). Later work (18) showed that at 95°C. a bark extract with over 10 percent solids could be obtained, but to avoid precipitation, it was necessary to heat the solutions with sulphite.

Initial Studies: When preparing bark for extraction in this work, one factor borne in mind was the known deleterious effect of storage under damp conditions (17). Normally slabwood bark was dried as described in the experimental part, but on one occasion a substantial sample of damp bark containing enough fine particles to prevent easy penetration of air into the heap during drying, gave yields of extract 45 percent lower than normal. It is believed that this lower yield arose from deterioration of the bark, as a result of drying over a longer than usual period of time at an elevated temperature under damp conditions with poor air circulation through the heap.

Another factor considered in preparing bark was particle size. In this connection a previous observation (1) that finely subdividing the bark of *P. radiata* has an important effect on the yield of extract, was confirmed. Screen analyses typical of two methods of grinding were as in Table 2, and because yields were substantially higher when using the fine bark, it was preferred.

From examples in Table 3 it will be seen that the rate of extraction of bark is quite rapid so that only a short time at temperature is necessary.

By heating a suspension of bark in aqueous sodium carbonate to 80°–85° C., extract for preliminary studies was obtained in about 25 percent yield at 16 percent solids concentration, as outlined in the flow chart. Such a scheme can be followed until the practical limit is reached. For example, it was noted in this case that filtration became appreciably slower by the time five batches of bark had been extracted. Although extracts containing 16 percent solids could be sprayed onto wood particles, frequently more concentrated extracts were obtained by rapid evaporation under reduced pressure in a climbing film evaporator. Many boards were bonded by aid of these extracts as shown by representative data given in Tables 4, 5 and 6.

From Table 4, it will be seen that when bark extract and paraformaldehyde were used to form *in situ* a resin bonding agent for smooth-one-side fiberboard, as much as 6 percent of extract was required to obtain a board comparable in strength to one incorporating 25 percent bark powder, as for example board 14, Table 1. This does not compare well with commercial fiberboard production where it would be unusual to add more than 2 to 3 percent synthetic resin. However, since these experiments were not extensive perhaps under different conditions less extract might be needed to achieve comparable results.

By a shift of emphasis from the above work it was found that bark extract could replace bark powder as a bonding component for particle boards and at the same time the restriction to high density, as referred to earlier, could be overcome.

In Table 5 results for boards 1 to 18, 19 to 46 and 47 to 62 show respectively the effect of varying the amount of bonding agent, the bark extract to paraformaldehyde ratio, and the amount of paraffin wax. A major gain in strength was obtained by increasing the amount of bonding agent from 2 to 4 percent. Variation in the paraformaldehyde to bark extract ratio did not appear to be a very critical factor, and the addition of some paraffin wax was obviously necessary to avoid high water absorption.

To the extract for boards 63 and 64 a relatively small amount of sodium-*ortho*-phenyl phenate had been added prior to room temperature storage at 25 percent concentration for 4 months. After this time a portion was spray dried using an inlet and outlet temperature of 240° and 100° C. re-

TABLE 5: SOD. CARBONATE EXTRACT AS A BONDING COMPONENT FOR PARTICLE BOARDS

Press temp.: 320°F. Caliper: 0.291 – 0.326 in. * Extract added as spray dried powder to freshly wetted particles and paraformaldehyde.

Board Number	Extr. Solids % O.D. Wood	Paraformaldehyde % O.D. Extr.	Wax % O.D. Wood	Max. p.s.i. when pressing	Time (min.) in press	Moist. Content % O.D.W.		Density	Mod. of Rupture	Water Absorption
						To Press	At Test	O.D. g./c.c.	p.s.i.	%/24 hrs.
1-4	2.0	6.0	1.5	180	15	38-43	7.9-9.6	0.69-0.71	1598	29.8
5-8	4.0	6.0	1.5	180	15	34-38	5.6-8.4	0.71-0.74	2569	26.4
9-12	6.0	6.0	1.5	180	15	32	8.2	0.73-0.75	2584	28.4
13-16	8.0	6.0	1.5	180	15	33-34	8.1	0.72-0.77	3034	27.6
17-18	12.0	6.0	1.5	180	15	32	4.7	0.82-0.86	3011	28.4
19-22	8.0	0	2.5	109	20	43-50	-	0.70-0.72	1313	38.2
23-26	8.0	3.0	2.5	109	20	42-50	6.5-10.2	0.71-0.72	1966	23.6
27-30	8.0	4.5	2.5	109	20	48	4.4-6.5	0.69-0.74	2186	23.9
31-34	8.0	6.0	2.5	109	20	49-51	6.7-9.2	0.70-0.77	2326	21.1
35-38	8.0	7.5	2.5	109	20	48-49	3.6-7.0	0.70-0.73	2154	26.3
39-42	8.0	9.0	2.5	109	20	48-49	5.5-7.9	0.70-0.75	2085	22.4
43-46	8.0	12.0	2.5	109	20	46-49	6.0-7.1	0.68-0.74	2228	23.2
47-50	8.0	6.0	0	109	20	53	7.6	0.70-0.72	2432	77.7
51-54	8.0	6.0	1.0	109	20	47	7.7	0.69-0.71	2666	26.8
55-58	8.0	6.0	1.75	109	20	51	7.3-9.1	0.69-0.73	2514	23.3
59-62	8.0	6.0	2.5	109	20	47	5.8-7.3	0.69-0.73	2523	24.2
63-64	4.0	6.0	1.5	180	15	32	6.1	0.72	2096	33.5
65-66	4.0 *	6.0	1.5	180	15	39	7.6-9.8	0.70	1952	27.3

TABLE 6: SODIUM CARBONATE EXTRACT AS A BONDING COMPONENT FOR PARTICLE BOARD

Press temp.: 320°F. boards 1-32; 270°F. boards 33-36; 320°F. boards 37-39.
Extract solids or synthetic resin: 8.0% of O.D. wood.
Paraformaldehyde: 6.0% of O.D. extract.
Wax: 1.5% of O.D. Wood Caliper: 0.250-0.400 in.
• = Minutes at 220°F. after pressing.

Board No.	Pressing: Max. p.s.i.	Pressing: Time, min.	Moisture (%O.D.W.): To Press	Moisture (%O.D.W.): At Test	Density O.D.gr./c.c.	Mod. of Rup. p.s.i.	Water Absorption % / 24 hr.
1-2	180	15	33	5.4	0.89-0.92	3963	25.4
3-4	180	15	33	8.1	0.72-0.74	3093	31.1
5-6	-	15	33	7.3	0.59	1653	34.0
7-10	180	20	33	6.4	0.73-0.81	3012	28.5
11-14	180	15	33	8.1	0.76-0.79	3044	27.6
15-18	180	10	33	9.8-12.0	0.76-0.80	2749	24.0
19-22	180	5	33	15.8	0.78-0.81	2149	24.6
23-24	180	5(30*)	39	12.8-14.1	0.69	2255	25.2
25-26	180	5(60*)	39	9.2-10.1	0.71	2639	25.7
27-28	180	5(120*)	39	6.6	0.72	3156	25.3
29-32(1)	400	12	16	10.4	0.73	3564	25.7
33-36(2)	400	7	14	9.7	0.75	4757	40.0
37-39(3)	400	7	14	7.6	0.73	3856	27.1

(1) and (2) Commercial urea formaldehyde particle board resin requiring respectively addition and no addition of catalyst.

(3) Commercial melamine-urea formaldehyde particle board resin powder blended dry with particles.

spectively. This spray-powder was stored for 8 months at room temperature and then used in boards 65 and 66 as a replacement for aqueous extract. Although, there was no appreciable difference between boards made using the stored spray-powder and the carbonate extract shortly before spray-drying, there was an appreciable drop in strength of boards 63 and 64 compared with boards 5 and 8. This is almost certainly associated with the unstable nature of the aqueous carbonate extract. Whereas this extract is unstable, even to the extent that at 25 percent solids it could become almost completely insoluble in hot water after standing up to four months in loosely capped jars, the spray-powder showed no further loss in effectivness as a bonding component after storage.

In Table 6, boards 1 to 6 show the dependence of physical properties upon density. Boards of higher density have also been produced using furnish of lower moisture content.

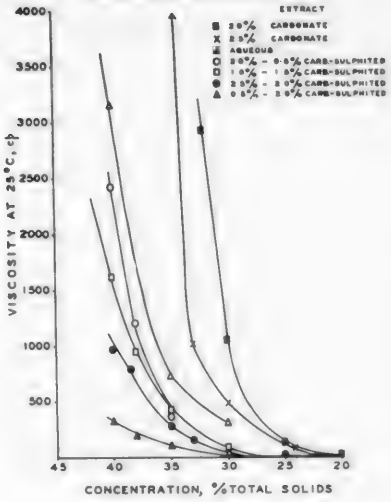
The effect of varying the pressing time and using two different consolidating pressures is shown by boards 7 to 22. As the pressing time was decreased, the modulus of rupture also decreased.

Boards 23 to 28, in Table 6 showed a gain in modulus of rupture when given a post-pressing heat treatment, but the real gain is masked by both a trend towards lower at test moisture content and a slight rise in density for longer heat treating times.

Results typical of those obtained using two different urea-formaldehyde resins and a melamine-urea-formaldehyde resin for bonding particles are represented respectively by boards 29 to 32, 33 to 36 and 37 to 39 in Table 6. These resins were used in accordance with the recommendations of their respective manufacturers. Another group of boards, analogous to boards 29 to 39 and having a similar inter-relationship of physical properties with bark extract resin bonded boards, was also produced using only 4.0 percent of either bark extract-aldehyde or synthetic resin. Except where melamine-urea-formaldehyde resin was used, the physical data for boards bonded with synthetic resins are apparently comparable with those obtained using bark extract-aldehyde resin. However, there is an appreciable difference in the moisture content of the board furnish and consequently the maximum or consolidating pressure at which the two classes of boards were pressed. Furthermore, attempts to press the bark extract class of boards at near 15 percent moisture content were unsuccessful. Pressing boards comparable to 3 and 4, Table 6, from furnish of near 25 percent instead of 33 percent moisture content led to an approximate decrease in modulus of rupture by one third.

Preparation and Study of Different Extracts: The encouraging results obtained using a sodium carbonate extract of bark as a component of the resin for bonding boards led to studies aimed at giving a better extract. It was shown that, when bark is extracted with 2.0 percent sodium carbonate, although the yield of extract could be doubled by raising the temperature from 30° to 60° C., increasing the temperature to 90° C. was of no particular advantage. Furthermore, the extract obtained at 60° C. was as effective as either of the others as a bonding agent component.

FIG. 1 VISCOSITY—CONCENTRATION



Apart from extract yield, change of viscosity with altered concentration and change of viscosity during storage are of interest (Figures 1 and 2). The former relationship is of value when considering the concentration at which an extract should be sprayed onto particles, while the latter is indicative of stability.

It was found that neither decreasing the amount of sodium carbonate nor replacing it by such substances as sodium or ammonium hydroxide or sodium borate led to an extract that was both more stable and less viscous at 30 percent solids. However, the effect of sulphite on an alkali extract seemed to be advantageous.

From Figure 1 it can be seen that, assuming a maximum viscosity and corresponding concentration above which it is impossible to spray cold extract onto particles, the use of sulphite permits extracts to be sprayed at a higher maximum concentration. When extracting with 2.0 percent sodium carbonate, for the alternatives of adding 0.5 percent sulphite either to

FIG. 2 VISCOSITY—TIME

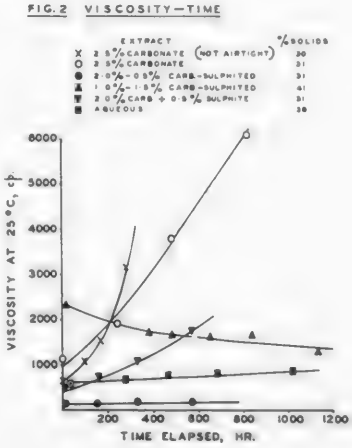


TABLE 7: DATA ON BARK EXTRACTS

No.	Extract Type	pH	Extract Solids, %	Yield, % (uncorr.)
1	Sod. carbonate/2.5%	7.7	4.6	21.4
2	Sod. carb./2.0%	7.1	4.5	19.3
3	Sod. hydrox./1.9%	8.0	4.1	23.3
4	Carb.-sulphited/2.0%-0.5%	7.4	3.7	21.0
5	Carb.-sulphited/1.0%-1.5%	6.4	3.4	19.4
6	Carb.-sulphited/0.5%-2.0%	4.9	2.9	17.8
7	Carb./2.0%+sulphite/0.5%	7.4	5.0	20.8
8	Aqueous	4.8	2.9	11.2
9	Aqueous	4.0	1.9	11.5
10	Metabisulphite/2.0%	3.9	2.5	15.4

the bark during extraction or to the dilute filtered extract before concentration (extracts 4 and 7, Table 7), viscosity-concentration data showed that the latter led to an extract of lower viscosity at comparable concentrations. A viscosity-concentration relationship similar to that for the latter was also obtained for an extract prepared using 2.0 percent metabisulphite as extractant (see extract 10, Table 7).

It was found that the addition of sulphite also improved stability, as can be seen from Figure 2 by comparing the curves for the 2.5 percent sodium carbonate extracts with those for the extracts to which sulphite had been added.

It is noted that hot aqueous extract, as well as being obtained in lower yield than carbonate extracts (Table 7), formed a precipitate when the hot filtered extract cooled. On the other hand, the filtrate including any precipitate could be concentrated to a clear syrup. This was relatively stable (Figure 2) and remained clear on dilution to 30 percent solids (Figure 1) below which a precipitate formed. A similar solubility effect has been encountered with aqueous extracts of other barks (24).

Various Extracts Used in Preparing Boards: On the basis of the above study further data, typical examples of which are shown in Table 8, were obtained using selected extracts as a component of the bonding agent for boards. All extracts were tested over a range of pre-press furnish moisture contents. This enabled the modulus of rupture maximum associated with optimum board furnish moisture content to be determined for each extract, from which comparisons between extracts could be made (Figure 3). More extensive experimental data than in Table 8 were used to derive the curves shown in this figure from which it becomes apparent that the best strengths were obtained using the 2.5 percent carbonate, the 2.0–0.5 percent carbonate-sulphited, and the 2.0 percent carbonate plus 0.5 percent sulphite extracts as indicated by Curve 1. The inherent variability of the test results makes it difficult to draw a valid conclusion as to which extract of these three gives the strongest boards. However, it does appear that the extracts containing 0.5 percent sulphite are probably better than the 2.5 percent carbonate extract, especially in view of their greater stability. The 2.0–0.5 percent carbonate-sulphite extract has the added feature of a lower viscosity at high concentration. It also appears that the optimum moisture content of the furnish is about 35 percent when using these three extracts as a bonding component.

Curve 2 in Figure 3 approximates to the results obtained using metabisulphite and 1.0 to 1.5 percent carbonate-sulphited extracts, both of which failed to lead to the production of boards as strong as those associated with Curve 1. In addition, the 24-hour water absorptions at maximum modulus of rupture were appreciably greater. Curve 3 is derived from data obtained from boards in which aqueous extract was used as a bonding component.

TABLE 8: DIFFERENT EXTRACTS AS A BONDING COMPONENT FOR PARTICLE BOARDS

Press temperature: 320°F. Extract solids: 4.0% of O.D. wood
Paraformaldehyde: 6.0% of O.D. extract.
Consolidating pressure: 180 p.s.i. Pressing time: 10 min.
Wax: 1.5% of O.D. wood Nominal caliper: 0.30 in.

Board No.	Moisture Content % O.D.W. To Press	Moisture Content % O.D.W. At Test	Density at Test g./c.c.	Mod. of Rupture p.s.i.	Water Absorption %/24 hr.
2.5% sodium carbonate extract - board pH at test 5.7-5.8					
1-2	20	6.7	0.71	1214	71.3
3-4	28	6.7	0.68	1441	50.7
5-6	32	6.8	0.72	1888	41.5
7-8	39	8.1	0.72	1722	36.5
1.0-1.5% carbonate-sulphited extract - board pH at test 5.4-5.7					
9-10	20	8.3	0.68	1671	59.5
11-12	25	9.8	0.70	1695	51.5
13-14	36	9.8	0.69	1459	39.0
15-16	47	12.8	0.68	915	36.4
2.0-0.5% carbonate-sulphited extract - board pH at test 5.8-5.9					
17-18	25	6.8	0.67	1665	47.1
19-20	31	6.6	0.70	1987	37.7
21-22	36	7.7	0.70	1755	35.7
23-24	44	8.4	0.72	1646	32.3
2.0% carbonate + 0.5% sulphite extract - board pH at test 5.7-5.8					
25-26	25	7.2	0.70	1609	53.8
27-28	30	7.1	0.69	1871	42.7
29-30	34	8.9	0.72	2049	39.5
31-32	43	11.8	0.74	1599	32.7
Aqueous extract - board pH at test 4.6-4.7					
33-34	21	11.4	0.68	1171	43.1
35-36	25	11.3	0.70	1243	35.6
37-38	30	11.2	0.73	1428	31.8
39-40	40	11.5	0.73	1339	28.3
2.0% metabisulphite extract - board pH at test 5.0-5.2					
41-42	18	9.1	0.68	1417	65.8
43-44	25	7.4	0.71	1743	50.0
45-46	31	8.1	0.72	1547	45.8
47-48	41	10.3	0.71	1098	39.8

TABLE 9: DISINTEGRATED PLANER SHAVINGS BOARDS

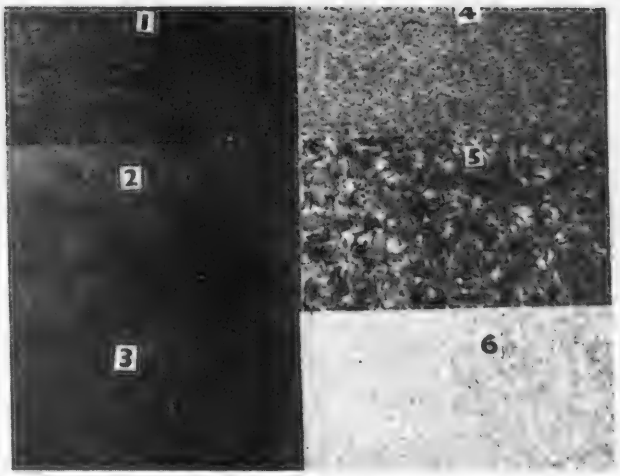
Press temperature, wax and paraformaldehyde: As in table 8.

Extract solids: % of O.D. wood, using 2.0-0.5% carbonate-sulphited extract.

Pressing method A: Slow increase in pressure to 180 p.s.i. in 3.5 min.

Pressing method B: Rapid increase in pressure to 180 p.s.i. in 0.5 min.

rd number	1-4	5-6	7-8	9
ract solids	6.0	6.0	6.0	5.0
isture content, % O.D.B. to press				
(a) middle layer	17.5	36.2	17.5	14.7
(b) outer layers	51.5	36.2	37.5	51.1
(c) overall	34.5	36.2	27.5	32.0
(d) at test	13.3	14.3	11.9	10.2
d furnish	Lot 1	Lot 1	Lot 1	Lot 2
ssing method - time, min.	A-15	B-15	B-15	A-15
per (in.)	0.75	0.71	0.71	0.69
. of rupture (p.s.i.)	1242	1997	2670	1604
. of elasticity (p.s.i.)	1.12×10^5	1.62×10^5	2.28×10^5	2.20×10^5
ity (g./c.c.)	0.64	0.67	0.69	0.60
ater absorption, % in 24 hr.	36.0	18.4	27.9	20.6



Types of board: 1) fiberized sawdust and bark powder; 2) dry-pulped fibers and bark powder; 3) dry-pulped fiber and bark extract; 4) selected sawdust and extract; 5) planer shavings and extract; 6) Board No. 5 after sanding.

In preparing the above boards with different extracts, a number of assumptions, not all of which are necessarily valid, were made in choosing the experimental conditions. However, because of the number of variables involved, it is necessary from a practical viewpoint to fix as many as possible. Thus, for example, it was assumed on the basis of earlier work that the use of 6.0 percent paraformaldehyde on an oven-dry extract basis, and a pressing time of 10 minutes would be reasonable for all extracts. It was also decided that no attempt would be made to adjust the pH of any extracts, including that of the aqueous extract.

Hardening agents other than paraformaldehyde were investigated, as indicated in Figure 4. Taking into account the lower density of the boards prepared using 4.7 percent of hexamine on an oven-dry weight of extract basis, there is no obvious difference in the results for the three different amounts of hexamine tested. Comparison of Curves 1 and 2 in Figure 4, the former being the same as Curve 1 in Figure 3, shows that hexamine did not give results as good as paraformaldehyde, but with other extracts hexamine may compare more favourably. Boards prepared with paraldehyde and metaldehyde as hardener were inferior to comparable boards in which paraformaldehyde was added as the hardening agent. The resin obtainable by co-polymerization of bark extract with polymethylol phenol in a ratio of 100:21 was considered as a bonding agent, but as seen from Figure 4, for the conditions used this did not lead to boards comparable in strength to those where paraformaldehyde was used as hardening agent. The above ratio of 100:21 was calculated on the basis of providing roughly two methylol groups for each formaldehyde molecule theoretically available from the amount of paraformaldehyde normally used.

From the above results, it is clear that the way in which a bark extract is obtained has an appreciable influence on its potential value as a component of a resin for bonding boards and that paraformaldehyde is the most satisfactory of the hardeners tested.

Disintegrated Planer Shavings Boards: When preparing 0.75 inch thick bark extract resin bonded boards using disintegrated planter shavings, as seen from Table 9, the best results were obtained by the combination of two techniques, namely, closing the press as rapidly as possible and making a board in which the furnish for the middle had a lower moisture content than the outer parts. For the conditions tested, the combination of both techniques gave boards with the best physical properties. Considering the latter technique only, comparison of boards 1 to 4 with board 9 shows that, by lowering the proportion of furnish in the outer layer from one-half

FIG. 3 DIFFERENT EXTRACTS AS BONDING COMPONENT

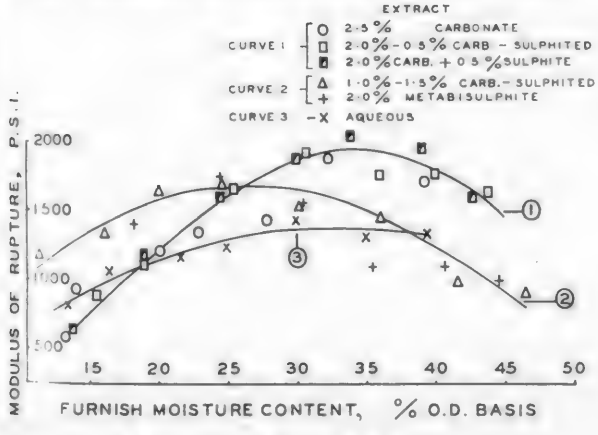
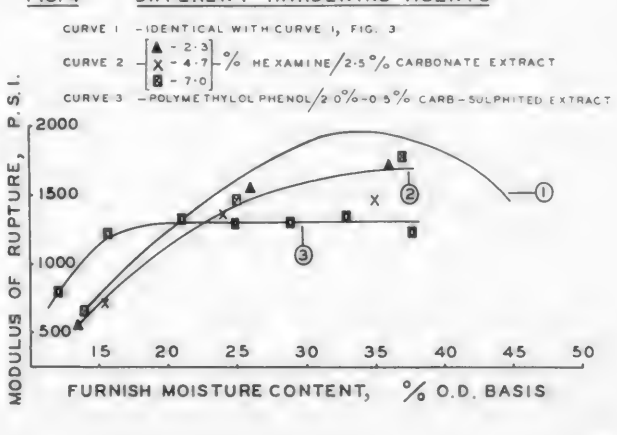
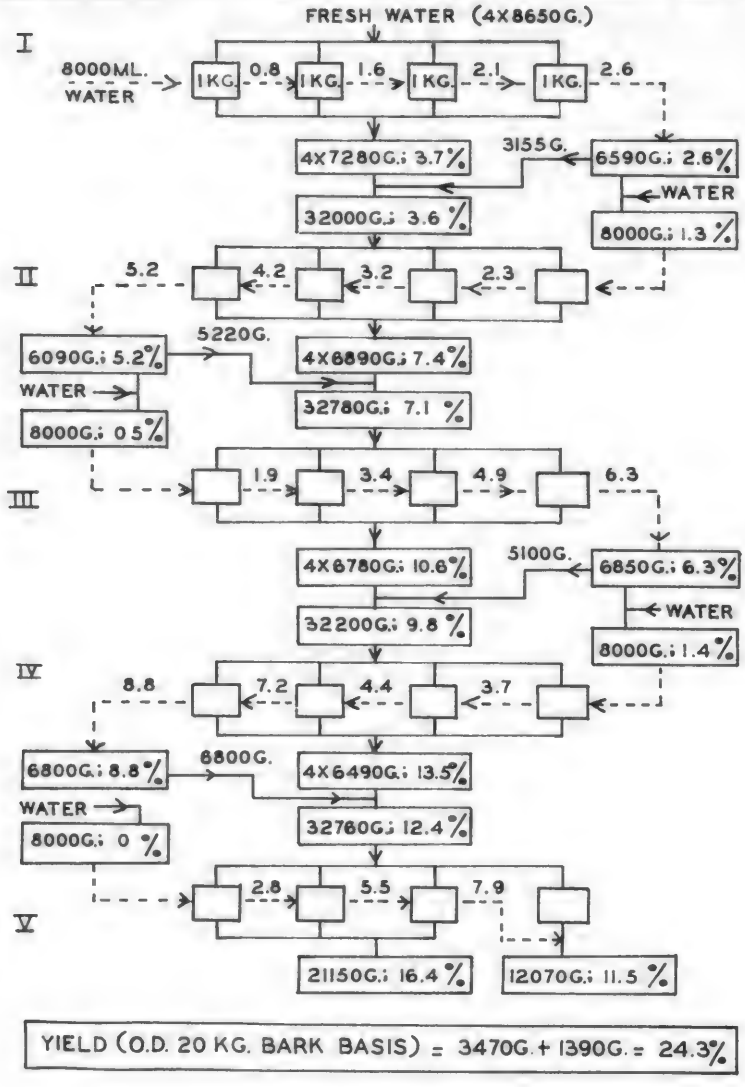


FIG. 4 DIFFERENT HARDENING AGENTS


CURVE 1 - IDENTICAL WITH CURVE 1, FIG. 3
CURVE 2 ▲ - 2·3, X - 4·7, ■ - 7·0 % HEXAMINE/2·5% CARBONATE EXTRACT
CURVE 3 - POLYMETHYLOL PHENOL/2·0%-0·5% CARB-SULPHITED EXTRACT
MODULUS OF RUPTURE, P.S.I.
2000
1500
1000
500
15 20 25 30 35 40 45 50
FURNISH MOISTURE CONTENT, % O.D. BASIS

FLOW CHART — SOD. CARBONATE EXTRACTION OF P. RADIATA BARK



to one-fifth of the total, the overall moisture content can be substantially reduced with an accompanying increase in moduli of rupture and elasticity.

Experimental

Bark: Bark of *Pinus radiata* D.Don from 30-year old plantations in the Taupo–Kinleith area of the North Island of New Zealand was collected as pieces dislodged where sawmill slabs are conveyed to a chipper. That portion of the bark passing through a 1-inch mesh screen was rejected. The accepted part was dried as soon as possible in loosely woven sacks, either on top of a Coe-drier or for about 48 hours in a veneer kiln at 160° to 170° F. Dried bark with a moisture content of 7 to 10 percent was stored, without detection of further deterioration, for use as required. An instance of suspected deterioration of bark during handling is discussed above. Dried bark was reduced in size by hand to pass a 1-inch mesh screen and broken up further in an 8 inch laboratory Bauer pulper fitted with "breaker" plates. From this, finely ground bark was produced by using the same machine fitted with No. 6946 pattern plates set at a nominal zero clearance. Coarsely ground bark was obtained by feeding slabwood bark through a hammermill. Bark powder screen analyses and yield of 2.5 percent sodium carbonate extract were used as checks on the comparable nature of different lots of bark. The tannin content, by method of Humphreys (14), was 13.5 to 17.3 percent.

Wood Furnish: Wood particles were obtained by screening *P. radiata* sawdust from a selected crosscut saw in a converting mill. For the boards in Table 1, excepting boards 9 and 14, the material passing a 6-mesh to the inch screen was fiberized dry in a laboratory Bauer pulper fitted with No. 6946 pattern plates set at a nominal clearance of 0.005–0.0075 inch. The resultant coarse fibrous pulp was sampled for moisture content and stored in polythene bags for use as required. For boards as in Tables 5, 6, and 8 and Figures 3 and 4, the sawdust fraction passing a 6-mesh to the inch screen, but retained by a twelve-mesh to the inch screen was used. After drying in a current of hot air to a moisture content of 10 percent or less, this was stored in closed drums until needed. For boards in Table 9, planer shavings were disintegrated in a Bauer pulper fitted with "breaker" plates. The accepted particles either were retained by a 12-mesh per inch screen after passing a 2-mesh per inch screen (lot 1) or were retained by a 6-mesh per inch screen after passing a 2-mesh per inch screen (lot 2).

To obtain fiber for boards as in Table 4 and boards 9 and 14 in Table 1, *P. radiata* chips were pre-steamed at 60 psi for 10 minutes in a Coe-Mco cooker and pulped in a 36-inch double disc Bauer fitted with No. B980 pattern plates operating at 1400 revolutions per minute.

The wax used was "Mobilcer A", a 50 percent solids non-precipitating type emulsion.

Flow Chart: In the flow chart, four lots of bark (4 x 1.0 kg. oven-dry weight) containing 2.5 percent sodium carbonate were used in each of five (I–V) extraction batches. Each lot of bark was extracted twice and then discarded. In the first batch (I), fresh water (4 x 8.65 kg). was used for the first extraction, but in subsequent batches, as shown by the vertical flow lines, the first extraction of fresh bark was carried out using extract from the previous batch. Extraction of each lot of bark for both the first and second extractions took 20 to 30 minutes during which time the temperature was raised to 80° to 85° C., then the bark slurry was filtered using a Buchner filter funnel, the filtrate being kept for use as required. In the second extraction of each lot of bark, as shown by the broken horizontal flow lines, the first lot of bark was washed at 80° to 85° C. with water or dilate extract using an 8:1 liquor to bark ratio but, because the same liquor was passed consecutively through each of the four lots of bark in any given batch the overall liquor to bark ratio for the second extraction was 2:1. Thus in any given batch the solids content of the liquor from the second extraction tended to reach half of the first extraction. Therefore, the liquor from the second extraction is alternatively called the wash liquor, and

conveniently used without disadvantage in making up the volume of filtrate obtained from the first extraction of fresh bark, to that required to maintain an 8:1 liquor to bark ratio for the first extraction of fresh bark in the next batch. Any excess wash liquor was diluted to 8.0 l. with fresh water for use in the second extraction of the next batch. Using the above procedure the effective overall liquor to bark ratio for the flow chart was:

$$\frac{\text{Liquor to bark ratio of each batch}}{\text{number of batches}}$$

or that is 8:5, the increase in solids content of the extract being approximately 3 percent per batch. Apparent discrepancies between the amount of ingoing and outgoing liquor for any extraction batch arise from losses associated with wetting the bark, and evaporation especially during vacuum filtration.

Bark Extracts: Bark extracts as in Table 7 was made by extracting each lot of bark twice using the same time, temperature, and liquor ratio. The first extraction was made with a solution of the extracting chemical, and the second extraction was made by adding only water, except for the sodium metabisulphite extraction. In this the procedure was reversed, the first extraction being with water and the second with a solution of 2.0 percent sodium metabisulphite on an oven-dry weight of bark basis. For the aqueous extraction there was little or no increase in yield obtained by carrying out a second extraction as shown by 8 and 9, (Table 7) which were obtained respectively by single and double aqueous extractions. In all extractions, hot solvent (8.0 l.) was added to the bark powder (2.0 kg.) in a stainless steel bucket. The mixture was stirred at 60° C. for 10 minutes and filtered. The filtrates from both extractions were combined, after sampling, sulphite was added if used, and the solution was evaporated on the same day under a reduced pressure of 24 to 26 inch of mercury in a climbing film evaporator. For simplicity, the term "sulphite" has been used to denote a mixture of sodium sulphite and sodium bisulphite in equal parts by weight. The indicated amount of sulphite was added as a 10 to 20 percent solution. Generally the volume of combined filtrate was about 11.0 l. and took 3 to 4 hours to concentrate. The concentration of extracts was determined by evaporating aliquots in an oven at 100° C. for 20 to 24 hours. The percentage of extractant used is expressed on an oven-dry weight of bark basis. In Table 7, the yields of carbonate-sulphited extracts were determined before addition of sulphite.

Viscosities of extracts were determined, at 25° C., using a Ferranti Model VL Couette coaxial cylinder type of viscometer operated at five different rates of shear, whence an average of five readings were obtained for calculating the viscosity of an extract in centipoises. For viscosity-concentration measurements a number of 150 gram samples of concentrated extract were taken with subsequent addition of the appropriate quantity of water to bring each solution to a particular concentration after thorough mixing. In the case of the concentrated aqueous extract, dilution was accompanied by slight warming to attain homogeneity. Unless stated otherwise viscosity-time measurements were determined on a sample of extract left to stand at room temperature in an airtight glass jar.

Board Preparation: Boards in Table 1 were prepared by weighing out portions of bark powder and either fiberized sawdust or dry fiber from bulk samples. To the latter component was sprayed sufficient water to adjust the moisture content to 45–55 percent on an oven-dried wood basis and a calculated weight of paraformaldehyde was mixed into the bark powder. This mixture was sieved into the fiber through a 36-mesh per inch screen, the combined board components being thoroughly mixed by tumbling in a polyethylene bag. To disintegrate lumps; the board furnish was then passed through a laboratory Bauer pulper fitted with "breaker" plates, after which it was sampled for moisture. A weighed amount of this furnish, sufficient for a 1-foot square board, was evenly sprinkled into a 1-foot square deckle box placed on a polished stainless steel plate. When evenly spread and levelled within the box the mass was consolidated by pressing down with a board cut to fit neatly into the box. While maintaining the pressure on this board, the box was removed. The board was then removed and the appropriate wire screen followed by a steel plate placed on top of the mat. Pressing was carried out in an electrically heated Archer laboratory press, pre-heated to the desired temperature.

Boards in Table 4 were prepared essentially as described above with provision for extract and wax emulsion to be sprayed onto the dry fiber prior to adding the paraformaldehyde.

In preparing boards in Tables 5 and 6, wood particles were tumbled in a concrete mixer while a mixture of bark extract and wax emulsion was added from a spray-gun. The extract had a solids content of 15 to 18 percent or 10 percent respectively when 8 or 4 percent of extract solids was added. To the mixture of wood particles, extract and wax emulsion was blended a calculated weight of paraformaldehyde powder. When using synthetic resin syrups (boards 29–39, Table 6) the wax emulsion, water and syrup containing 27 percent solids were mixed together prior to spraying, after which the hardener was added as a dry powder. Spray-dried extract (boards 65–66, Table 5) and melamine-urea formaldehyde powder (boards 37–39, Table 6) were blended into particles just sprayed with wax emulsion containing sufficient water to give the desired board furnish moisture content. Boards were formed in a deckle box as described previously, and pressed between matched, polished, stainless steel caul plates in a preheated Archer laboratory press with platen temperatures as indicated in the tables. The time to pressure was not more than 30 seconds and for boards pressed at 109 psi. the pressure was maintained for the whole pressing time, but at 180 or 400 psi. the pressure was maintained only until the desired degree of consolidation had been reached as indicated by distance pieces. After that, the pressure was steadily released to zero by the end of the pressing time.

In preparing boards as in Table 8 and Figure 4, wood particles were tumbled in a 10-gallon drum rotated on its side at 40 revolutions per minute while a mixture of 50 percent solids wax emulsion and extract was sprayed onto the particles through a hole in the lid. The solids content of the extract added to the wax emulsion was 30 percent in the case of aqueous or metabisulphite extracts and 25 percent for other extracts. Boards referred to in Figure 4 were obtained using the same press temperature, pressing time, consolidating pressure, amount of wax, and amount of resin solids as in Table 8. When either paraformaldehyde or metaldehyde was used as the hardener, this was mixed into the sprayed particles as a powder. Hexamine and paraldehyde being water soluble, were added to the wax emulsion and extract before spraying. Polymethylol phenol was mixed into the bark extract in the ratio for bark extract: polymethylol phenol of 100:21. Board forming and pressing were as for Tables 5 and 6.

Polymethylol phenol syrup was prepared on a small scale by a method analogous to one recently described for preparation on a pilot-plant scale (12). The resultant polymethylol phenol syrup had 48 percent solids and viscosity 34 c.p. at 25° C.

In preparing layered boards as in Table 9, essentially the same procedure as described for boards in Table 8 and Figure 4 was used for addition of extract, wax emulsion and paraformal-

dehyde to disintegrated planer shavings, after the moisture content had been suitably adjusted either by spraying on water or drying in a current of air at 220° F. The furnish for the outer layers was divided into two equal parts. Apart from using furnish of moisture content appropriate to the outer or inner layer, and apart from differences noted in Table 9, forming and pressing techniques were similar to those relating to Table 8 and Figure 4.

Board Testing: After removing boards as in Tables 1, 4, 5, 6 and 8 from the press they were left to stand overnight in the laboratory before testing. Strips of board 1.75 inches wide were cut in order to determine breaking loads using a Bauer modulus of rupture testing machine with a 32 pound per minute rate of loading and an 8-inch span. The thickness of each strip was measured at the point the load was to be applied. From each board pressed, 6 strips were obtained and of these 3 were broken with the one side up and 3 with the other side up. Modulus of rupture was calculated from breaking load and caliper, the mean of six determinations being reported as the modulus of rupture for a particular board. Moisture content at time of testing and water absorption were determined using 10 of the 4- by 1.75 inch samples cut from the 12 pieces remaining after measuring the breaking loads. The edges of samples were not sealed prior to determining water absorption at ambient temperature with an average water head of 3 inches. For pH determinations, 2.0 grams of shredded board were boiled in 20 ml. of distilled water for 2 minutes and cooled to room temperature. With the exception of boards in Table 1, the average density of each board was calculated from the weight and volume, the latter being determined by immersing, in mercury, four 4- by 0.75-inch strips cut from 2 of the 12 pieces mentioned above.

Boards in Table 9 after removal from the press were conditioned for two weeks at 65 percent relative humidity and 68° F. then cut into two 11- by 4-inch strips. The density of each strip was determined from its weight and dimensions. The breaking load and deflection under load of each strip were measured across a 6-inch span using a modified National Forge crush testing machine in which the testing head moved at 0.5 inch per minute.

Summary

Some success had been achieved using powdered *Pinus radiata* bark as the major component of a bonding agent for dry felted smooth-one-side boards. Extensive studies have also been made on both the preparation and use of extracts of *P. radiata* bark in the production of bark extract-aldehyde resin bonded particle boards.

A method of obtaining extract at a 16 percent solids concentration without evaporation is described. Extracts, prepared at different temperatures with and without the addition of reagents such as sodium carbonate, sulphite and bisulphite, have been examined in terms of their viscosity-concentration relationship at 25° C., and their stability at ambient temperatures as shown by viscosity-time data. Optimum extract yields were obtained without loss of quality in relation to end use, by extracting finely divided bark at an elevated temperature with aqueous sodium carbonate. The disadvantageous relative instability of such extracts can be substantially overcome by the addition of sulphite.

A formulation of board furnish, consisting of wood particles, bark extract, paraformaldehyde and wax emulsion, and a selection of pressing conditions have been established on the basis of experimental results. Bark extract-formaldehyde resin bonded particle boards have been prepared that are apparently comparable with those bonded with urea-formaldehyde resins. To compare the relative effectiveness of various bark extracts when used as the major component of a resin for bonding particle boards, the modulus of rupture maximum has been determined from modulus of rupture—board furnish moisture content data for a number of extracts. Tests have also been carried out using hexamine, paraldehyde, metaldehyde or polymethylol phenol as an alternative for paraformaldehyde. These results showed that the method of obtaining a bark extract has an appreciable influence on its ultimate contribution to bonding particle boards and that paraformaldehyde is the most satisfactory hardener.

When preparing homogeneous bark extract-formaldehyde resin bonded boards it has been found that the optimum moisture content of the furnish is about 35 percent. This has been reduced to an overall value of approximately 20 percent by preparing layered disintegrated planer shavings boards in which the furnish used for the outer layers, representing about one fifth of the total, had a moisture content of near 50 percent.

Conclusion

Under appropriate conditions, it is probable that satisfactory bark extract-formaldehyde resin bonded particle boards could be produced using *P. radiata* bark as a source of extract, but only further work can establish this more definitely.

Acknowledgements

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WORLD-WIDE

Forest Products News

FAO Yearbook of Forest Products Statistics

The following is a condensation of the summary from the 13th Yearbook, prepared by the Forestry Division of FAO, in collaboration with the Economic Commission for Europe. The 160 page book is available from FAO, or International Documents Service Columbia University Press, 2960 Broadway, New York 27, New York, for $2.50.

World Situation, 1958

The world timber harvest in 1958 increased to 1,664 million m³ from 1,663 million m³ reached in 1957. Removals of saw and veneer logs and the "other industrial wood" group were greater while pulpwood-pitprops and fuelwood volumes declined. The categories of roundwood removals may be compared by regions in Table 1. (next page)

The increase in volume of industrial wood removals since the beginning of the decade has been greatest in the USSR, with Asia and Europe following. In the regions with highly developed industries, fuelwood occupies a subordinate position in the timber harvest. In Central America, South America, Africa and Asia, however, the bulk of reported removals are fuelwoods. The relative importance of fuelwood has declined during the past decade, from about 52% of the total world removals in 1948, to about 4 percent in 1958. However, these fuelwood removal figures are not strictly accurate since a large volume of fuelwood remains unrecorded and unreported, being used for domestic needs by the local inhabitants.

Forests in World Economy

The timber harvest in rough value terms is shown in Table 2. This calculation uses unit values based on global averages and much of the data on which they are grounded are insufficient. However, the estimates are significant in that they show the direction of the change that took place in the timber harvest in 1957 and 1958. Values represented by forest products other than wood (seeds, nuts, rubber, cork, tanbark, gums, bamboo, reeds, etc.) and the "intangible" values of the forest are not included in Table 2.

Table 2.—TIMBER HARVEST BASED ON ROUGH GLOBAL AVERAGES

	1957	1958
	Millions of US dollars	
Products of sawlogs[a]	14,900	15,300
Products of pulpwood[b]	13,000	13,300
Pitprops	1,200	1,100
Other industrial wood	900	900
Fuelwood	3,300	3,300
Total	33,300	33,900

[a]Sawnwood, sleepers, veneers, plywood.
[b]Paper, paperboard, fibreboard, particle board.

World Trade in Wood Products

Table 3 shows that Africa is still the region which exports the greatest proportion of its industrial wood harvest. Africa ships out primarily hardwood logs while Europe, the second most prominent exporting region, sends mostly processed wood and woodpulp and paper manufacturing plant products. As far as the total volume of exports in terms of roundwood equivalent, Europe leads with 74.3 million m³, followed by North America with 54.1, USSR, 10.8, Asia, 7.9 and Africa 4.9 million m³.

Table 3.—INDUSTRIAL WOOD EXPORTS BY WORLD REGIONS

Region	Industrial wood exports[a] as percentage of removals
Europe	38
U.S.S.R.	4
North America	17
Central America	11
South America	12
Africa	45
Asia	8
Pacific Area	7
World	18

[a]Forest products in terms of roundwood equivalents.

The total value of imports and exports is shown in Table 4. The saw- and veneer-log group exhibits the only gain in value in 1958, as shown by a comparison of the detailed export values reported in 1957. All other forest products registered losses in export values from the previous year.

Table 4.—TOTAL VALUE OF IMPORTS AND EXPORTS BY WOOD REGIONS

	1958	
	Total value	
Regions	Imports	Exports
	Millions of US dollars	
Europe	2,707	2,492
U.S.S.R.	76	249
North America	1,598	1,893
Central America	86	19
South America	344	84
Africa	294	121
Asia	386	263
Pacific area	168	39

Sawnwood

Production: The decline in the output of the world's sawmills which began in 1955 has reversed position, as shown by the small increase (nearly 2%) from 1957. The greatest volume of both coniferous and broadleaved sawngoods (97.2) was again produced by North America. Except for Africa and Asia, all other areas showed an increased output. A rise of 6% from 1957 increased the output of the USSR to 87 million m³, making it the leader in the producing countries.

The USSR and the US lead in the production of coniferous sawnwood, which comprised about 80% of the total world sawnwood output. The report on broadleaved sawnwood production shows US—15.1 million m³, USSR—13.1, Japan—2.8, and France—2.3.

Trade: Europe shipped nearly 46% of the world exports of coniferous sawnwood, and North America shipped 36%. Canada, Sweden, USSR and Finland respectively are leaders in the exporting of softwood in 1958. Europe leads North America, USSR and Brazil in the event of

Table 1.—CATEGORIES OF ROUNDWOOD REMOVALS BY WORLD REGIONS

Region	Sawlogs, veneer logs and logs for sleepers		Pulpwood and pitprops		Other industrial wood		Fuelwood	
	1948	1958	1948	1958	1948	1958	1948	1958
	Percentage of total removals							
Europe	34	35	16	23	8	7	42	35
U.S.S.R.	24	36	9	15	20	16	47	33
North America	55	55	23	26	6	4	16	15
Central America	14	16		3	1	1	85	80
South America	9	12	1	1	1	1	89	86
Africa	5	7	1	0.2	1	2	93	91
Asia	17	29	2	7	3	4	78	60
Pacific area	51	55	4	10	3	3	42	32
World	30	35	11	14	8	7	51	44

Table 5.—PULPWOOD PRODUCTION BY WORLD REGIONS

Region	Wood pulp production			
	1948	1952	1957	1958
	1,000 metric tons			
North America	18,640	23,080	29,235	29,070
Europe	8,155	9,865	14,320	14,180
Asia	460	1,485	2,975	3,010
U.S.S.R.	987	1,959	2,756	2,896
Pacific area	130	210	520	540
South America	100	180	235	255
Africa	10	30	135	135
Central America	70	70	125	140
Total	28,550	36,880	50,300	50,225

coniferous sawnwood, at this report. The leading sawn softwood importer in 1958 was the US, with 1.6 million stds., while the United Kingdom, leader in 1957, imported less than 1.3 million stds.

Plywood

Production: A new record level was achieved in the world production of plywood in 1958—almost 13 million m³—an increase of 1.2 million m³ from 1957. 59% of the total was produced in North America. US, Canada and Japan all showed increases in percentage terms.

Trade: The export volume reported for 1958 was 30,000 m³ greater than in 1957, a total of 1.1 million m³. Europe and Asia both exported the largest volume, each 415,000 m³. Japan, Finland and the USSR were leading exporting countries.

The US continues to be the leading importer with 40% of the world total. 73% of that from Japan, 11% from the Philippines and 5% from Canada.

Pulp

Production: After reaching an all-time high of 50.32 million tons in 1957, the total world output of wood pulp slipped to 50.22 million tons in 1958. North America and Europe, the two regions with the largest production, both showed small declines. To provide a capsule portrait of the growth in volume of wood pulp production by regions, Table 5 shows the output at the beginning, midpoint and end of the recent decade.

Trade: Europe leads the field with the largest 1958 exports, 4.8 million tons. North America exported 2.48 million tons, a slight decline from the 1957 level. Again, Sweden was the leading exporting country, with over 31% of the 1958 world export tonnage. Canada and Finland followed. The United Kingdom and the US were the main importing countries in '58, as in all recent years. Spain reported nearly double import than in 1957, while Japan imported only 28% of the 1957 figure.

Pulp Products

Newsprint: The production of newsprint declined 1½% from 1957, an output of 12. 14 million tons. This is the first decline in over a decade. Canada, US, and the United Kingdom slipped a little, while Finland, Sweden and Japan reported some increased newsprint production.

Paper other than newsprint: This group consists of about 39% printing and writing paper. It had a production increase of a little over 2% from 1957, with increases in all regions except Africa and the Pacific area. The US, the Federal Republic of Germany and the United Kingdom continued to lead in production.

Paperboard: Over 21 million tons of paperboard were produced in 1958, making it a record year, and increasing the total over 2% from the previous year. Since 1948, world production of paperboard has increased 79%.

Fibreboard: A record was also set in the world production of fibreboard totalling 3.6 million tons in 1958. Since 1948, the tonnage has risen 98%, with the US and Sweden as leading producers in this line report. Compressed fibreboard continues to increase its share in the total output, being up to 58% in 1958 of the total reported production.

Trade: Total export volume of pulp products were reduced from 11.1 million tons in 1957 to 10.9 million tons in 1958, largely because of reduced exports of newsprint, printing and writing paper and paperboard. Canada still leads with 76% of the world total, followed by Finland. The US, again the largest newsprint importer, reduced its imports by 309,000 tons from the previously reported year, while the United Kingdom, second in this line, increased its intake. Regional trade balances for pulp products are shown in Table 6.

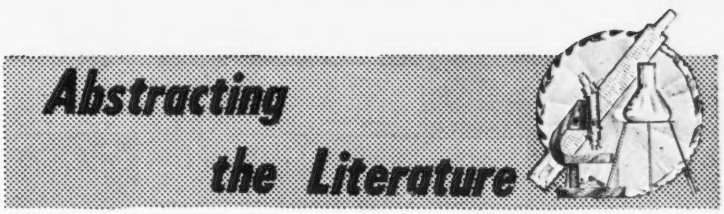
Particle Board

World production of particle board increased from 800,000 tons in 1957 to 905,000 tons in 1958. Over 61% of the particle board production was in Europe, with more than 31% in the Federal Republic of Germany alone. There is no data available for 1958 from the US. Production statistics and trade figures for particle board are not yet complete in most of the countri

Table 6.—PULP, PAPER, AND FIBREBOARD PRODUCTION BY WORLD REGIONS

Region	Net trade[a]											
	Newsprint			Other paper			Paperboard			Fibreboard		
	1948	1957	1958	1948	1957	1958	1948	1957	1958	1948	1957	19
	Thousands of metric tons											
Europe	+405	+155	+160	+510	+920	+835	+ 30	— 45	— 50	+45	+115	+
U.S.S.R.	+ 3	+ 56	+ 59	— 1	— 55	-----	— 5	— 64	-----	-----	-----	
North America	— 35	+770	+840	+225	+160	+150	+120	+225	+235	+40	+ 20	+
Central America	—100	155	—125	— 95	—130	—145	— 5	— 45	— 50	— 5	— 2	
South America	—250	405	—390	—125	—165	—155	— 40	— 35	— 45	-----	— 10	
Africa	— 80	120	—130	—135	—190	—205	— 45	— 30	— 35	— 5	— 2	+
Asia	—135	215	—190	—135	—265	—250	— 30	— 60	— 60	-----	— 25	
Pacific area	—145	180	—170	—130	— 90	—120	— 25	— 13	— 14	— 5	— 1	+

[a]Exports+; imports —.



PULPING

Ingström, P. and Back, E. The resin in parenchymatous cells and resin canals of conifers. 8. The proportion of canal resin in *Picea abies* Karst. pulpwood. Svensk Papperstidn. 62, no 16: 545–53 (Aug. 31, 1959). [Engl.; Swed. and Ger. sum.] *cf. abstr.* no. 3071.

In conifers used for pulp mfr., natural resin occurs in parenchymatous cells and in resin canals. The canal resin is freed and becomes easily accessible to chemicals, e.g., in sulfite pulping, whereas the parenchymatous resin is retained with in hydrophilic cells wall as long as these walls are not damaged in subsequent pulp trmts. The distribution of total resin according to these two types is, therefore, of fundamental importance for tech. problems, such as chem. and mech. pulp deresination and pitch control. The rel. proportion (by wt.) of canal resin in the total nonvolatile resin of *P. abies* pulpwood has been detd. to be 45%, with considerable variations between trees but small variations between height levels within a tree. The proportion of volatiles in freshly secreted (canal) resin has been estd. at 19%. Total canal resin in *P. abies* occupies 0.34% of the wood vol., 40% constituting radial and 60% representing vert. resin canals. The vol. of the lumen in radial and vert. canals is 44 and 55% of the total canal vol., resp. All data reported are weighted av. values for stemwood disks. Systematic variations of resin-canal parameters from the pith to the cambium in these disks are illus., and the charac. features of *P. abies* resin ducts are discussed. 22 ref. [A.B.I.P.C. 30:5]

Hartler, N., and Ostberg, K. Impregnation [of chips] for sulfate cooking. Svensk Papperstidn. 62, no. 15: 524–33 (Aug. 15, 1959). [Swed.; Engl. and Ger. sum.]

The effects of chip size, pressing, wood moisture, presteaming, preimpregnation, and cooking temp. on the amt. of screenings obtained in lab. kraft cooks were investigated. A theory of kinetic conditions during a sulfate cook is presented, in which the effects of all factors can be expressed in a single "f-value." The lower this value the greater the probability of crit. conditions leading to a high amt. of screenings. Exptl. results were in good agreement with this theory. Steaming to facilitate chip impregnation is recommended only in exceptional cases when no other measure seems effective. It must be done with utmost care if decreases in pulp yield or quality are to be avoided. Decreasing the chip thickness is the simplest and safest way of redg. the amt. of screenings. Even where the amt. of screen rejects is acceptable, a decrease in chip thickness combined with an increase in Roe no. will be beneficial in that it may increase the yield of high-grade pulp. For lab. kraft cooks, chip dimensions of 40 by 25 by 3 ($\pm$0.5) mm. are recommended to minimize the risk of high screenings with a Roe no. of up to 7. For cooking batches of 50–100 g., the chip width should be reduced to 3 mm. to increase the no. of chips and thus minimize differences between charges. 10 ref. [A.B.I.P.C. 30:5]

COMPOSITION BOARD

Eisner, Karol, and Koleják, Milan. Some problems in the manufacture of wood-particle board by the method of shortened pressing. Drevársky vyskum 3, no. 2: 223–42 (1958); Referat. Zhur., Khim. No. 15: 528 (1959). [Slovakian; Russ., Ger., and Engl. sum. Abstr. only available)

In the accelerated method of wood-particle board pressing (or the method of "steam impact") the surfaces of the board are sprayed with water at the rate of 100 g./sq. m., then the board is pressed between two hot tin plates. The upper plate is mounted in the press so that the upper surface of the board comes in contact with the hot plate during the closing of the press. Under these conditions the amt. of water used for spraying the upper surface of the board can be increased to 400 g./sq. m. At a press temp. of 140° C., however, the best results are obtained at a water consumption of 100 g./sq. m. Since the resin binder is cured during storage, tight stacking of the pressed board before cooling is recommended. [A.B.I.P.C. 30:7]

Gorskii, B. Z., Pogrebnyak, Z. F., and Ivanova, M. I. The use of furfural resins in constructional materials. Visnik Acad. Budivn. Arkhitekt. Ukrain. R.S.R. no. 3: 47–8 (1958); Referat. Zhur., Khim. no. 16: 483 (1959). [Ukrainian; Russ. sum. Abstr. only available]

Phenol-furfural resin (*I*) for use as a binder in the mfr. of wallboard and wood-particle board is prepd. as follows: 100 parts (by wt.) of cvryst. phenol, 60 parts of tech. furfural, and 13.3 parts of sodium hydroxide are condensed for 1 hr. at 80° C.; the temp. is then lowered to 60–65°, 40 parts of 37% formalin and 10.3 parts of 25% ammonia are added, and the mixt. is allowed to stand for 30–35 min. The *I* obtained has a pH of 7–8, a dryness of 50–60%, a refractive index of 1.39–1.404, and is stable for 10–14 days. The binder emulsion is prepd. by mixing 100 parts (by wt.) of softwood ext. with 100–120 parts of water until foam is formed (2–3 min.), then adding gradually 166 parts of *I* and mixing for 15–25 min. Wallboard and wood-particle board contg. *ca.* 10% of *I* had a vol. wt. of 0.81 and 0.80 g./cu. cm., a water absorptivity of 2 and 8%, and a bending strength of 281 and 331 kg./sq. cm., resp. [A.B.I.P.C. 30:7]

Kalnin', I. A new method of manufacturing thermal insulation materials. Kholodiln. Tekhn. no. 6: 57–8 (1958); Referat. Zhur., Khim. no. 17: 507 (1959). [Russ. Abstr. only available]

A description is given of a process for the mfr. of thermal insulation panels and molded articles from porous matls., such as wood bark, chopped straw, and reed, using UF resin as the bonding adhesive and a polymerization catalyst. The props. of prods. mfd. from the bark of willow, pine, and cork oak are tabulated. [A.B.I.P.C. 30:7]

BYPRODUCTS

Wafer, Joseph M. The outlook for tall oil production and consumption. Paper Trade J. 143, no. 48, 30!3 (Nov. 30, 1959.)

Possible future prodn. of tall oil is forecast up to 1965, and markets for tall oil prods. are discussed. The const. decline in gum rosin prodn. and indications of a similar situation devg. in wood rosin may lead to tall oil becoming a large factor as an alternate source of supply of rosin. Although the pulp and paper ind. has continued to expand, it is not likely that kraft pine pulp prodn. will become sufficiently large to permit tall oil rosin to replace wood rosin completely. In the protective coating ind., tall oil fatty acids have made considerable inroads due largely to the wide price fluctuation of soya bean oil with which it competes. [A.B.I.P.C. 30:7]

Mednikov,F. A. Multistage treatment of softwood shavings. Trudy Leningrad. Lesotekhn. Akad. no. 87: 49–54 (1959); Referat Zhur., Khim. no. 19: 441 (1959). [Russ. Abstr. only available]

Multistage extn. of softwood shavings with gasoline, water, and alkali yields a carotene-chlorophyll concentrate, a medicinal ext., and wood wool (excelsior). A description is given of the equipment necessary to carry out the process, and the possibility is indicated of obtaining other end prods., such as vitamin-contg. wood flour to be used as a cattle-feed suppl. [A.B.I.P.C. 30:7]

PHOTOMICROGRAPHY

Larson, Philip R. (U.S. Forest Serv., Lake States Forest Expt. Sta.) Preparation of small wood blocks for photomicrography. Stain Technol. 34, no. 3: 155 (May, 1959).

In the prepn. of small wood blocks for photomicrography, a simple technique has been devised whereby the wood surface can be made highly reflective and yet permit photographs of extremely fine detail to be made. The procedure involves prepg. a smooth cross-sectional surface on a sliding microtome, thoroughly drying the specimen, rubbing the prepd. surface on a glass plate covered with finely ground levigated alumina, removing the excess alumina powder, and polishing the surface of a soft cloth. [A.B.I.P.C. 30:5]

PULPING

Dickson, George (Stetson-Ross Machine Co.), **and Hensel, J. S.** (Am. Pulpwood Assoc.) Chip blanking can mean more chips for pulp mills. Paper Trade J. 143, no. 44: 32–4 (Nov. 2, 1959).

In chip blanking, excess lumber is removed from board by special cutters which make it into valuable chips for pulp and paper. The new Stetson-Ross chip blanker is described; the unit is available as a top-head, sidehead, or combination chipper and is mounted on a motorized planer. [A.B.I.P.C. 30:7]

Echols, R. M. (U.S. Forest Service, Southern Forest Expt. Station). Estimation of pulp yield and quality of living trees from paired-core samples. Tappi 42, no. 11: 875–7 (Nov., 1959).

The selection of trees with an acceptable growth rate and with high sp. gr. for seed orchards or for controlled breeding depends upon accurate testing methods and a std. method of comparison. The wood quality index chart provides numerical ratings for comparing the past performance of trees. It may also be used to predict future devt. under certain known conditions of growth. The index is based on the vol. of a segment of stem for which only the diam. inside the bark need be known, and on age and sp. gr. which may be detd. from large increment cores. Sp gr. and ring-width measurements should be made along a diam. line through the pith and should include all of the wood from bark to bark. This can be accomplished by extg. two increment cores of 10 mm. diam. from the hole of each tree selected for testing. The cores are taken from opposite sides of the tree at a height of 3 ft. above the ground. The removal of large increment cores from the stems of pine trees apparently has no effect on future growth and devt., but the holes should be plugged to reduce the exudation of gum. 9 ref. [A.B.I.P.C. 30:7]

PROPERTIES

Gukova, E. M., and Krylov, N. A. The effect of cations of different valences on the electric conductivity of wood. Nauch. Doklady Vyssh. Shkoly, Lesoinzh. Delo no. 2: 183–5 (1958); Referat. Zhur., Khim. no. 14: 474 (1959). [Russ. Abstr. only available]

Samples of oak-, birch-, and aspenwood were dried to const. wt. and immersed in 25% solns. of sodium, barium, and aluminum chloride and in distd. water for 24 hr. at *ca* 20°C. For all wood species, the elec. conductivity *(I)* of the samples immersed in distd. water increased slowly until the moisture content reached about 30%, then continued to increase rapidly. Impregnation of wood with salt solns. resulted in an increase of *I*. At the end of the impregnation period, the *I* of the samples in the various salt solns. was inversely proportional to the radius of the salt cations. [A.B.I.P.C. 30: 7]

Horiike, Kiyoshi, and Kato, Shoshiro. The heat of wetting of wood. I. Hydrogen bonding and swelling of wood. J. Japan Wood Research Soc. 5, no. 5: 181–5 (Oct., 1959). [Jap.; Engl. sum.]

The heats of wetting *(I)* by water and various org. solvents have been detd. for sprucewood (*Picea jezoensis* Carr.) at 30°C. The data suggested a correlation between the *I* and the degree of swelling *(II)* of the wood. The swelling behavior is explained from the hypothesis that the *II* bears a direct relationship to the intensity of hydrogen bonding between the wood constituents and the swelling agent. Although the values of *I* observed for piperidine the pyridine deviated from this hypothesized relationship, they could be brought in line with the other data after correction for hydrogen-bond energy. 14 ref. [A.B.I.P.C. 30: 7]

DECORATIVE LAMINATES

Shcherba, N. S. Decorative laminates. Steklo; Byul. Gosud. Nauch.-Issled. Inst. Stekla no. 2: 20–2 (1958); Referat. Zhur., Khim. no. 17: 509–10 (1959). [Russ. Abstr. only available]

A process recently devd. for the manufr. of decorative, light- and heat-resistant laminates consists of impregnating smooth-surfaced veneer from birch-, oak-, chestnut-, or redwood with a 25–30% acl. soln. of MUF resin (U.S.S.R. pat. 104,581). Drying at 50–65°C. for 2–2.5 hr., and pressure-laminating to plasticized glass at 140–150°. The lamination time is 20–25 min. and the pressure 20–25 kg./sq. cm. The surface of the laminate has a smooth glassy appearance, does not need polishing, and retains the texture and color of wood. It can be washed with cold or hot water, and is not damaged by contact with hot objects. [A.B.I.P.C. 30: 7]

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